Above the level of mean high water, as shown on the U.S. Geological Survey 7½ minute quadrangle map of Belfair, Washington, the Union River and its tributaries drain an area of 23.4 square miles. Elevations in the basin range from sea level to 1760 feet at the summit of Gold Mountain. This mountain and nearby Green Mountain to the north are the highest land forms in the report area and have a distinct affect on the general precipitation pattern. The mean annual precipitation over the basin from 1946-60 was estimated to vary from about 80 inches in the area of these mountains to about 56 inches in the lower part of the basin (pl. 4).

Continuous streamflow records have been collected at two locations in the Union River system (table 10 and pl. 3). Gage No. 0630 near Bremerton was installed in 1946 and operated through the 1959 water year. Gage No. 0635 near Belfair has records extending from 1947 through 1959. The record of Gage No. 0630 is unaffected by upstream diversion, but since 1956 the flow has been regulated somewhat by the City of Bremerton's Casad Dam and reservoir. Immediately downstream from Gage No. 0630 the City of Bremerton diverts from three to four thousand acre-feet of water annually for its municipal water supply. This and many other small downstream diversions, primarily for irrigation and domestic supply, are reflected in the records of Gage No. 0635. The regulatory effect of Casad Dam also has influenced the flow pattern at this gage for the period 1956-59. The actual yield of the drainage area above Gage No. 0635 is, therefore, somewhat greater than that indicated by the available record. This was considered in the runoff analysis and partially accounts for the sizable difference between the adjusted measured mean annual runoff shown for Gage No. 0635 in table 47, and the estimated mean annual effective precipitation shown for the Union River at confluence number 0 in table 48.

The analysis indicated that the entire basin produced about 39 inches or 49,000 acre-feet of mean annual effective precipitation during the period 1946-60 (table 48 and pl. 4). If the original data are extrapolated further by means of annual runoff ratios to represent the period 1934-59, the potential mean annual yield of the basin would be about 37 inches or 46,400 acre-feet. The statistics listed in table 49 for the two gages on the Union River show a moderately low measured annual runoff variability, indicating that the yield is reasonably consistent and reliable. Coefficients of variation are somewhat higher for the downstream gage (0635), but this is probably due in part to the City of Bremerton's large annual diversion.

The streamflow regimen of the Union River during the low flow period is best exemplified by the discharge-duration hydrograph of Gage No. 0635 (fig. 75). If summer flows during the years 1948-55 are representative of long-term trends, the lowest flows can normally be expected during the last week of August and the first three weeks of September. For any specific day during the latter part of this period, the average discharge at this gage can be expected to be less than 14.5 cfs about 1 year out of every 100. For days during the middle of this period, 50 percent of the time the flow should be greater than 20 cfs and 50 percent of the time less than 20 cfs. During the first part of the period there is a 2 percent chance of a daily discharge being equal to or greater than 25 cfs. Similarly the probable expectancy of having a given flow at this gage on a certain day during the months June through October can also be found from this graph.

In general, the relatively flat, narrow band of curves for Gage No. 0635 in fig. 75 indicates that ground-water is the primary contributor to the flow of the Union River during the summer. The abrupt rise displayed by the upper two curves, however, shows that direct surface runoff becomes an important factor during September and October. Additional low-flow information on several tributaries and at other locations on the main stem is presented in figs. 31-38 and tables 10-13, 23-26 and 48.

Twin Lakes and Lider Lake are the only significant sources of natural surface storage within the Union River basin (table 50). The artificial reservoir behind Casad Dam, however, provides a total storage capacity of about 4000 acre-feet at its normal full operating level (fig. 83).

MISSION CREEK

Mission Creek and its tributaries comprise the major drainage system lying adjacent to and west of the Union River Basin. The main stream has its source along the western base of Gold Mountain approximately 8 miles west of Bremerton and courses in a south-southwesterly direction for about 9 miles to its mouth near the head of Hood Canal. Mission Lake is also situated at the foot of Gold Mountain and its outlet discharges into the main stem from the east about a mile from the source of Mission Creek (confluence No. 7). About 6 miles farther downstream, the outlet stream from Tiger Lake contributes to the system. This 3-mile long tributary (confluence No. 3) is often dry in summer, especially in the marshy area along its upper reaches. A few other important tributaries drain small marshy areas located mainly in the western half of the basin.

The surface drainage area of Mission Creek basin, as measured above the mean high water level established by the U.S. Geological Survey, is 13.6 square miles. Elevations range from sea level to about 1680 feet on Gold Mountain. This orographic feature has a distinct effect on climate and, combined with an unobstructed southwest exposure to prevailing storms, causes, on an average, greater amounts of precipitation to occur in this part of Mission Creek basin than anywhere else in the report area. For the period 1946-60 the mean annual precipitation at these higher elevations was estimated to be over 80 inches while farther south in the lower part of the basin the lowest mean annual precipitation received was about 57 inches (pl. 4).

Continuous streamflow data are available for two locations on the main stem of Mission Creek (table 10 and pl. 3). The upper gage (No. 0645), installed in 1945 and operated for approximately 8½ years, was ideally situated to measure runoff from Gold Mountain. The lower gage (No. 0650), installed about the same time and operated for 7½ years, provides runoff information for roughly the upper third of the basin. No runoff data are available for the major remaining portion of the watershed so the yield and streamflow regimen are less certain in the lower reaches.

Based on the analysis for the period 1946-60, the entire Mission Creek watershed produced an average effective precipitation or potential runoff of 37 inches or 26,600 acre-feet annually (table 48 and pl. 4). If the Grapeview runoff ratios are used to adjust the data to the period 1934-59, the potential mean annual yield would be about 35 inches or 25,200 acre-feet. The coefficients of variation (table 49) for like periods of record at the two gages indicate that percentagewise variations in measured annual runoff are nearly identical at these locations and the dependability of the yield ranks about average among other major watersheds in the report area.

Low-flow discharge-duration hydrographs for the two gages show that summer flows are more variable at the upstream site than farther downstream (figs. 75 and 76). Ground-water discharge provides a greater percentage of the downstream flows, consequently low flows are somewhat more dependable in the lower reaches of this stream. If the data are representative of future conditions, the percent chance that a given mean discharge will occur on a certain day can be estimated from these graphs. For example, there is a 1 percent chance that the mean daily discharge on any September 20 will be less than 0.011 cfs, at the site of Gage No. 0650. These curves show that the lowest flows can be expected during the period from about August 25 to the end of September. Low-flow information is also provided for this stream system in figs. 39-46 and tables 10, 11, 14, 15, 27-30 and 48.

The major sources of natural surface water storage in the Mission Creek basin are Mission and Tiger Lakes. Smaller quantities are retained in Larson Lake, another small unnamed lake and several intermittent marsh areas (table 50).

TAHUYA RIVER

The Tahuya River and its tributaries form the largest individual stream system in the report area. Originating in a swampy area on the west side of Green Mountain, approximately 9 miles west of Bremerton, the Tahuya River flows in a general southwesterly direction for about 20 miles and enters Hood Canal near the town of Tahuya. Gold Creek, one of the most important tributaries, joins the main river about a mile from its source (confluence No. 21). This rather short tributary begins in a swampy beaver-pond area between Green and Gold Mountains and flows approximately $2\frac{1}{2}$ miles due west to its confluence with the river. Panther Lake, one of the larger lakes in the basin, discharges into the main stream by way of Panther Creek about 4 miles downstream from the source (confluence No. 19). Of the many small tributaries along the lower reaches of the Tahuya River, Little Tahuya Creek is probably the most important. This stream drains Lake Wooten, Haven Lake and Twin Lakes and joins the main stem of the Tahuya River about 12 miles from its source (confluence No. 12).

The Tahuya River basin ranges in elevation from sea level at the mouth of the river to about 1760 feet at the summit of Gold Mountain. The total surface area drained by the system is 45.1 square miles as fixed by the level of mean high water shown on the U.S. Geological Survey 15-minute quadrangle map of Potlatch, Washington.

Mean annual precipitation on the Tahuya River basin, as estimated for the years 1946-60, varies from a low of about 59 inches near Camp Pond to highs of around 80 inches near the summits of Green and Gold Mountains and nearly 70 inches in the extreme southwestern part of the watershed (pl. 4).

Continuous streamflow data have been collected at 5 different locations in the Tahuya River system (table 10 and pl. 3). Gage No. 0680 was located to measure runoff from nearly all of the basin; however, this gage was in operation for only $3\frac{1}{2}$ months during the summer of 1947. The other gages, beginning with the year 1946, provide a minimum of 8 complete years of continuous record but only Gage No. 0655 on Gold Creek was still in operation at the time of this report. The Gold Creek gage has over 15 years of record representing the longest continuous source of streamflow data in the Kitsap Peninsula area. Considering the other 3 stations, Gage No. 0675 measured runoff from the upper third of the basin, Gage No. 0670 recorded the contribution of Panther Lake, and runoff from the mountainous area was measured by Gage No. 0660.

A study of daily discharges during extended dry periods shows that the Tahuya River becomes influent between Gages 0660 and 0675. That is, some of the flow seeps into the ground in this reach and adds to the immediate ground-water reservoir. Some of this water reappears at the surface to become streamflow farther downstream, but there is evidence to indicate that sizable quantities eventually discharge into the channels of other adjacent stream systems through ground-water migration. The high unit runoff of nearby Dewatto Creek implies that this system could be the recipient of some of this water.

Based on an analysis of available data, the potential mean annual yield of the entire Tahuya River basin during the period 1946-60 was estimated to be 42 inches or 104,400 acre-feet. If these figures are adjusted for the longer period, 1934-59, the potential mean annual yield would be about 40 inches or 98,900 acre-feet. An examination of the coefficients of variation in table 49 shows that measured annual runoff in the Tahuya River basin has been about as consistent as that of both Mission Creek and the Union River basins. Of the individually gaged areas within the Tahuya River system, annual runoff from Panther Creek basin displayed the least variability followed closely by runoff from the Gold Creek drainage. Except for the period 1946-50, records from gage 0660 on the main stem exhibited the largest coefficients of variation.

Summer-month discharge-duration hydrographs illustrating low-flow conditions in the Tahuya River basin are presented in figures 76, 77, 78 and 79. These graphs exhibit available data recorded at the 4 main gages and show that a variety of low-flow conditions exist within this basin.

The closely grouped family of curves obtained from the Gold Creek record (fig. 76), indicates that ground-water runoff is an important factor in maintaining low flows in this stream. If these curves are representative of long-term trends, the lowest flows each year can be expected to occur sometime during the period from about August 10 to the end of September. The 99 percent-of-time duration hydrograph essentially represents the lowest mean flow to be expected on any given day and, based on this curve, the mean-daily discharge at this station should seldom be much less than 0.32 cfs.

The expanded set of curves for Panther Creek (fig. 78) indicates there is little dependable base flow and summer streamflow can be expected to vary considerably from year to year. Panther Lake has a natural regulatory affect on the flow of Panther Creek and often during September the lake is lowered enough to cause the outlet stream to go completely dry. This is suggested by the pronounced dip in the discharge-duration hydrograph curves around September 10.

In comparing the discharge-duration hydrographs of Gages 0660 and 0675 on the main stem (figs. 77 and 79), it is evident that a sizable portion of the summer flow is lost in the course of travel between the two stations. It is unlikely that evaporation could account for all of this loss so it is logical to assume that the river is influent in this reach. The exact length of the influent reach is indeterminate from existing data, but the 1947 summer record of Gage No. 0680 shows that the river becomes effluent again in its lower reaches. As a result, low summer flows are reasonably reliable in the upper and lower reaches but drop off rapidly in the vicinity of Gage No. 0675 where, in fact, the stream is intermittent. Farther upstream near Gage No. 0660 late summer flows should seldom fall below 0.15 cfs.

In 1961 a dam was constructed on the Tahuya River between Gage No. 0660 and the confluence of Gold Creek. The project raised the level of Tahuya Lake from its original natural elevation of 582.5 feet to 590.1 feet, thus increasing the storage capacity from about 100 acre-feet to 1650 acre-feet (fig. 84). This increase in storage, together with changes in the hydraulic characteristics of the river has probably caused the above described flow regimen to be altered somewhat. Natural storage is also provided by the other large lakes previously mentioned and many smaller lakes, ponds and intermittent marshes (table 50).

RENDSLAND CREEK

Rendsland Creek drains 8.74 square miles of the remote southwestern part of the Western Upland. From its source in Tee Lake, the stream courses southwesterly about 5½ miles to a point on Hood Canal about 3 miles northwest of Tahuya. The highest points within this basin are found along the crest of the Hood Canal bluff which forms the western divide. Here elevations exceed 640 feet while farther inland the watershed divide is generally somewhat lower.

The extreme southwestern part of the Kitsap Peninsula receives the initial impact of storms passing through the gap between the Black Hills and the Olympic Mountains; consequently, mean annual precipitation is comparatively high in this area. An analysis of available data indicated that, during the 1946-60 period, the higher western parts of the Rendsland Creek basin probably received an average of over 70 inches a year while the headwater areas received a few inches less (pl. 4).

Continuous-record streamflow data is completely lacking in Rendsland Creek basin so the potential yield was evaluated with the aid of data collected in nearby areas. During the 15-year period, 1946-60, mean annual effective precipitation on this watershed was estimated to be about 47 inches or 21,800 acre-feet (table 48 and pl. 4). For the 1934-59 period the estimated potential yield was 45 inches or 20,700 acre-feet. Since annual climatic trends are quite uniform throughout the study area, annual runoff variability was probably similar to that of other nearby streams.

Though Rendsland Creek drains a sizable area, there apparently is little ground water held in storage to maintain flow throughout the summer. No information is available on upstream low flows, but two independent observations at the mouth showed the stream to be dry. This indicates a highly variable daily streamflow regimen supported primarily by direct surface runoff.

Natural surface storage in the Rendsland Creek basin occurs in Robbins Lake, U Lake, Nigger Slough and several other small lakes and swamps (table 50).

DEWATTO CREEK

From its source about a mile southeast of Holly, the main channel of Dewatto Creek trends in a south-southwesterly direction paralleling Hood Canal for about 9 miles until it reaches Dewatto Bay. Excluding the area tributary to the tidal estuary, Dewatto Creek drains an area of 22.0 square miles. Like Rendsland Creek basin, the higher elevations are found along the western watershed divide. This divide lies at the crest of the bluff along Hood Canal and in places its elevations exceed 720 feet above mean sea level. Altitudes along the eastern divide generally average about 100 feet lower.

An analysis of data for the period 1946-60 indicated that mean annual precipitation on this basin varied from over 70 inches along the higher western border to less than 65 inches in the most easterly areas (pl. 4).

Gaging station No. 0685, located about two miles upstream from the mouth of Dewatto Creek, provides continuous-record streamflow data from mid 1947 through the 1954 water year and from mid 1958 through the cut-off date of this report (table 10 and pl. 3). These records accurately describe the natural flow regimen of Dewatto Creek since little diversion or regulation takes place above this site.

Based on studies of precipitation and evapotranspiration, the potential mean annual yield for this entire watershed during the period 1946-60 was 47 inches or 54,900 acre-feet (table 48 and pl. 4). If the longer period, 1934-59, is considered, the mean annual effective precipitation or potential yield would be about 45 inches or 52,000 acre-feet.

The above streamflow records adjusted to the 1946-60 period, however, gave a mean annual runoff at Gage No. 0685 of nearly 50 inches, thus indicating that measured runoff is greater than the potential runoff (table 47). The unequal size of the tributary drainage areas and inherent inadequacies of the basic data probably account for most of this difference, but there is evidence to indicate that some of the discrepancy could be attributed to inter-basin ground-water transfer. Though existing information affords no definite proof, it appears that ground waters originating in the adjacent Tahuya River basin could be contributing flow to the Dewatto Creek system through continuous aquifers which are not hydraulically controlled by surface topography.

The low annual-runoff coefficient of variation shown for Dewatto Creek in table 49 signifies that the yield of this stream is more consistent and dependable than other major drainages in the report area. It is possible that a runoff lag resulting from the large ground-water contribution to this stream system may have some influence in reducing the annual runoff variability.

The discharge-duration hydrograph of Dewatto Creek (fig. 77), with its closely grouped family of curves, further points out the dominent role of base flow in the regimen of this stream. These curves show that ground-water contributions, practically without exception, maintain a flow of over 10 cfs at Gage No. 0685 during the rain deficient summer months. Since a pattern of extended base-flow recession is apparent, it is difficult to specify a particular time when the lowest flows can be expected. The general trend, however, indicates that the minimum flow usually occurs sometime in August, September or early October. Percentagewise, the expected flow range for days in June, July and August is very low, implying that ground-water runoff is a major contributor during these months. The sudden rise of the low percent-duration curves in September and October, however, reflects an increase in direct surface runoff from fall rains.

The largest quantities of natural surface storage in the Dewatto Creek basin occur in Cady Lake, Shoe Lake, Larson Lake, Oak Lake and Erickson Lake (table 50). A few smaller lakes, ponds and marsh areas also prevail throughout the drainage area.

THOMAS CREEK

As a consequence of the numerous steep bluffs along much of the Kitsap Peninsula's shoreline, drainage in the peripheral areas is characterized by many small, short streams and springs. Among these, Thomas Creek is outstanding because it displays an unusually high and constant discharge rate throughout the year.

Thomas Creek heads near the crest of the Hood Canal bluff just east of Holly and follows a precipitous north-northwesterly course to a small cove located about three-quarters of a mile below its source. The steep surface drainage area tributary to Thomas Creek occupies only 0.38 square mile, so direct runoff lasts for only a short period of time after each storm.

Miscellaneous measurements made during the normal dry season, however, show that the stream has a rather constant flow in excess of 2 cubic feet per second (table 11). While plate 4 shows a potential yield or mean annual effective precipitation for this area of only 46 inches, a constant minimum discharge rate of 2 cubic feet per second would produce at least 1450 acre-feet or 72 inches of runoff annually. The great discrepancy between potential and actual yield confirms the assumption that the flow of Thomas Creek is maintained largely by ground water that originates outside of the topographic boundaries of this watershed. The same type of phenomenon also occurs in many other small coastal drainages but the effect is usually not as pronounced.

DOGFISH CREEK

Two major tributary branches characterize the drainage network of Dogfish Creek basin. The West Fork of Dogfish Creek, originating in a marshy area of Big Valley about 4 miles north of Poulsbo, follows the valley in a general southerly direction (confluence No. 3). The East Fork has its source in the Northern Upland about 2 miles northeast of Poulsbo and trends in a southwesterly direction toward Big Valley. Approximately a mile north of Poulsbo the two forks join to form the main stem which then continues southwesterly for about three-quarters of a mile to Liberty Bay. Altitudes in the basin range from sea level to over 480 feet, and the system drains a surface area of 7.63 square miles.

As a result of the Olympic Mountain rain-shadow effect, mean annual precipitation in the Dogfish Creek area was estimated to average only 37 inches during the 1946-60 period (pl. 4). Similarly, the potential yield or mean annual effective precipitation for this basin was estimated to be only 18 inches or 7200 acre-feet for the same 15-year period (table 48 and pl. 4) and 17 inches or 6800 acre-feet for the longer 1934-59 period. The record of Gage No. 0700 on the main stem, however, shows that the actual measured runoff was somewhat greater. Adjusting the 13 available years of record to be representative of the 1946-60 period, the area contributing above this gage was found to have produced a mean annual runoff of 24 inches (table 47). The inability of available basic data to accurately delineate actual conditions could be responsible for this large difference, but there is also evidence that the discrepancy can be partially attributed to an inflow of ground water from adjacent areas outside the basin. An exceptionally large contribution from springs in the Lofall-Poulsbo trough tends to bear out the latter possibility. Though its lower annual water production would imply higher variability, the coefficients of variation in table 49 show that, with the exception of Dewatto Creek, the annual yield of this stream has been more consistent than that of most other streams in the report area.

While most streams in the southern part of the area exhibit minimum flows toward the end of August or in September, the lowest flows in Dogfish Creek usually occur in late July or early August. This may in part be due to the difference in climate between the northern and southern areas, but the effect can more likely be attributed to large irrigation diversions and heavy withdrawals from certain springs by the City of Poulsbo water department.

A slow spring recession rate followed by a well-maintained summer base flow characterizes the discharge-duration hydrograph of Dogfish Creek (fig. 78). Generally, this family of curves shows only a slight vertical spread, so flow in Dogfish Creek has deviated little from its normal pattern from year to year during the indicated five-month period. However, during the extreme low-flow period, a radical dip occurred in the 99 percent hydrograph curve. This anomalous departure was probably produced by excessive diversion and doesn't necessarily represent the natural flow regimen of the stream. At times when water is being diverted, daily discharges as low as 1.0 cfs, can be expected at the gage, but under natural conditions, the flow should seldom be less than 2.5 cfs.

The watershed has no lakes but some surface storage is provided in the large marshy area near the source of the West Fork of Dogfish Creek.

CHICO CREEK

Chico Creek and its four major tributaries drain a 16.0 square-mile area located a few miles northwest of Bremerton and immediately northeast of Green and Gold Mountains. Wildcat Creek, situated in the northwestern part of the basin, is the largest tributary and receives runoff from over one-third of the entire area. Originating at Wildcat Lake, this stream courses southeasterly for nearly 2 miles to its confluence with Lost Creek about 2 miles above tide water (confluence No. 6). The area immediately south of the Wildcat Creek watershed is drained by Lost Creek which heads approximately a mile east of Green Mountain and follows a general northeasterly course for about 3 miles to its confluence with Wildcat Creek. Below this point the main stream is referred to as Chico Creek. Dickenson Creek flows into Chico Creek (confluence No. 2) from the south about a mile downstream from the Wildcat-Lost Creek confluence. The discharge from Kitsap Creek, also from the south, enters the main channel of Chico Creek a short distance below Dickenson Creek (confluence No. 1).

Since the basin partially encompasses the northeastern slopes of Green Mountain, it has altitudes as high as 1560 feet above mean sea level. Precipitation received in these upper areas is comparable to that near the summits of Green and Gold Mountains, but the existence of these mountains tends to shelter the remaining part of the basin from prevailing storms and greatly reduces precipitation at lower levels. From an analysis of 1946-60 data, mean annual precipitation was estimated to vary from about 75 inches at the highest elevations to approximately 48 inches in the lower northeasterly areas (pl. 4).

Continuous streamflow records were obtained at gage No. 0720 from mid 1947 through the 1950 water year (table 10 and pl. 3). These data, adjusted to the 1946-60 period, indicated a mean annual runoff of 33 inches for Chico Creek basin (table 47). This differs only slightly from the estimated mean potential yield for the same period of 35 inches or 30,200 acre-feet per year (table 48 and pl. 4). The mean annual effective precipitation for the 1934-59 period was estimated to be about 33 inches or 28,600 acre-feet. Such a small discrepancy can probably be attributed to inherent inadequacies in the existing data although it is possible that some ground water is lost from the Chico Creek area to several nearby small streams tributary to Chico Bay.

Since large portions of Chico Creek basin are geologically and topographically unsuited for storing appreciable amounts of ground water, the streams in this drainage system tend to recede rapidly after a storm, and little water is retained to maintain base flow during dry periods. The 1950 water-year hydrograph at gage No. 0720 (fig. 27) illustrates the general low-flow tendency of Chico Creek and shows that there is a high probability that the stream will go completely dry during the months of August, September or October. Miscellaneous measurements in table 11 imply similar low-flow trends on the tributary streams. In addition to the surface storage in Wildcat and Kitsap Lakes, some storage exists in the Dickenson Creek drainage in Beaver Dam Lake and in several marshes in the northern part of the Chico Creek basin (table 50).

GORST CREEK

Gorst Creek drains a 9.08 square-mile area located at the northeast end of the Union River-Gorst Creek Valleys. Having its source near the community of Sunnyslope, the main stream initially follows a north-northwesterly course toward the Old Navy Yard Highway. After crossing the highway, the course gradually changes toward the east, paralleling the highway, until it reaches the western end of Sinclair Inlet. Parish Creek (confluence No. 3) and Heins Creek (confluence No. 4), the two major tributaries, join the main stem immediately west of Gorst.

The southeastern extension of the Gold Mountain upland is the highest area in the basin. This area, with altitudes in excess of 1300 feet, receives an average of as much as 70 inches of precipitation annually, while the lowest parts of the watershed receive only about 50 inches (pl. 4).

Streamflow data in this basin consist of a few miscellaneous measurements on the main stem and major tributaries (table 11). Mean annual potential runoff was therefore estimated by correlation of continuous record streamflow data from nearby basins with precipitation and evapotranspiration data. This analysis indicated that the Gorst Creek watershed should have produced a mean annual effective precipitation during the 1946-60 period of about 37 inches or 18,000 acre-feet (35 inches or 17,100 acre-feet for the 1934-59 period). Since the City of Bremerton diverts water from Gorst Creek for its municipal system, the remaining usable supply could be somewhat less than indicated by these figures.

Though corroborating data are lacking, low-flow measurements indicate that a sizable base flow is maintained in Gorst Creek during summer months. Such a condition would produce a relatively uniform flow pattern with moderately low daily variability, making this stream system a dependable source of supply.

A small amount of natural surface storage is provided by Heins, Alexander and Jarstad Lakes (table 50).

BLACKJACK CREEK

Lying immediately south of Port Orchard, the 12.4 square-mile area drained by Blackjack Creek displays the characteristic low-relief glacial topography found throughout most of the Kitsap Peninsula. Altitudes range from sea level to about 520 feet at the divide near Square and Matthews Lakes and from this area the main drainage follows a general northeasterly course for approximately 6 miles to Sinclair Inlet at Port Orchard.

The regional analysis of data for the period 1946-60 indicated a range in mean annual precipitation in this basin from about 48 inches in the north to about 55 inches in the south (pl. 4). The mean annual effective precipitation or potential yield of the area (table 48 and pl. 4) was estimated to be 30 inches or 19,600 acre-feet for the 1946-60 period (28 inches or 18,600 acre-feet for the 1934-59 period). However, three years of streamflow data from Gage No. 0725, adjusted to the same period, indicated a mean annual runoff of only 24 inches (table 47). This difference implies either inadequate data or a loss of ground water to adjacent drainages.

Although there are numerous water rights to divert the flow of Blackjack Creek, ground-water discharge into the stream system is generally sufficient to maintain a reasonably high base flow. The minimum recorded instantaneous flow at Gage No. 0725 was 6.7 cfs (table 10), and the 1950 water-year hydrograph (fig. 28) illustrates the usual flow trend.

Several small lakes, including Deep Lake, Berry Lake, Square Lake and Matthews Lake, provide surface storage within the basin (table 50).

BURLEY CREEK

Burley Creek heads about a mile west of Long Lake and follows a southerly course for approximately 5 miles to Burley Lagoon at the end of Henderson Bay. In general, the stream basin occupies the southern half of the Burley Creek-Blackjack Creek Valley. Elevations in this 10.8 square-mile basin are generally low and range from sea level to slightly above 460 feet.

Data obtained during the period 1946-60 show that there is a gradient in the mean annual precipitation over this area ranging from about 50 inches in the east to 54 inches in the west (pl. 4). As an average for the basin, mean annual effective precipitation was estimated to be 30 inches or 17,400 acre-feet during the same period (table 48 and pl. 4), and 28 inches or 16,500 acre-feet for the 1934-59 period. Adjusted streamflow records obtained at Gage No. 0730, however, indicate a mean annual runoff for the 1946-60 period of nearly 34 inches (table 47). Like other drainages in the report area where potential runoff is less than actual, Burley Creek displays an exceptionally high base flow implying that some of the ground-water contribution is derived from precipitation originally collected in adjacent watersheds.

The large ground-water contribution suggests low variability and a rather consistent flow pattern during summer months. Since the base flow is quite uniform and recedes at a slow rate (fig. 28), the lowest flows may occur anytime from June through October, though the probability for an annual minimum is greater during August, September or early October. Based on past records, the annual minimum daily discharge at Gage No. 0730 should average about 14 cfs, and should seldom be less than 10 cfs. Low-flow data for this stream and some of its tributaries are listed in tables 10 and 11.

Surface water storage in Burley Creek basin is limited to Horseshoe Lake and a few intermittent ponds (table 50).

MINTER CREEK

Minter Creek and Huge Creek, its major tributary, drain a 15.9 square-mile area located a few miles west of Burley. Both streams follow converging southerly courses to their confluence near the south end of the basin (confluence No. 4). From this point the main stem continues southward for approximately a mile to its mouth at the head of Minter Bay.

Within the basin elevations range from sea level to somewhat more than 520 feet, and no outstanding topographic features are exhibited to modify precipitation. There is, however, a general decreasing gradient from north to south, and for the 1946-60 period, mean annual precipitation was estimated to range from 53 inches to 57 inches (pl. 4).

While little information, other than a few miscellaneous measurements, is available for Minter Creek proper, continuous streamflow records have been collected at Gage No. 0735 on Huge Creek since mid-1947 (tables 10 and 11, pl. 3). These records, adjusted to the 1946-60 period, showed a mean annual runoff of about 25 inches for this part of the watershed (table 47). In contrast to this, potential yield studies for the same period (table 48 and pl. 4), indicated that the area should have produced 32 inches or 11,300 acre-feet (30 inches or 10,700 acre-feet for the 1934-59 period). Again inter-basin ground-water transfer is implied, though it is not certain whether the water reappears as runoff in other parts of Minter Creek basin or is actually lost to adjacent drainages. Considering the entire Minter Creek basin, mean annual effective precipitation was estimated to be 32 inches or 27,000 acre-feet for the 1946-60 period.

It is interesting to note that, of the streams with five or more years of record, the annual runoff of Huge Creek produced the highest coefficients of variation (table 49). Such a degree of variability, however, is not excessively high when compared with yields of streams in more arid regions.

Tributaries in the northern part of the basin are mostly intermittent, but farther south increasing ground-water discharge maintains relatively uniform perennial base flows. The latter condition is apparent in the lower reaches of Huge Creek by the general shape of its discharge-duration hydrograph (fig. 79). The flatness of these curves shows a nearly constant discharge during the indicated months while the extremely narrow spread implies a low percentage variation in the summer flow pattern from year to year. The lowest flows, which have seldom been less than 3.5 cfs, have the greatest chance of occurring around the end of August but could appear almost any time during the period shown.

Lake Flora, Wicks Lake and several small marsh areas provide some surface water storage in the Minter Creek watershed (table 50).

FLOODS IN THE REPORT AREA

By E. G. Bailey, U.S. Geological Survey

A flood is defined as a condition that prevails when the waters of a stream exceed the capacity of its normal channel and overflow the adjacent flood plains. In the area of this report, floods occur only during the fall, winter, and early spring seasons and result primarily from rainfall. During the flood season the highest discharges are most prevalent from November to February.

There is little recorded information in the area on the destructive effect of floods in relation to loss of property or human life. The streams are relatively small and flood damage has been confined largely to culverts, small bridges and other man-made channel structures. However, flood potential is always a factor of concern and it is desirable to appraise the flood threat to the extent that available knowledge will permit.

The highest momentary peak discharge in a water year is used as the significant flood for analysis in this report, although not every yearly peak discharge is of flood proportion. Also, such use of the annual flood does not imply that there may be only one flood of major importance each year; other peak flows occurring within the same water year sometimes have but slightly less magnitude than the annual flood. The annual maximum discharges of three streams in the Kitsap Peninsula area are shown in table 51. These data were collected at gaging stations that were operated on a year-around basis. The data are presented also in graphical form in figure 80 which illustrates the variations in annual peak discharges that may be expected.

MAGNITUDE AND FREQUENCY OF FLOODFLOWS

The magnitude and frequency of recurrence of floodflows at the designated gaging points, also have been estimated for these three streams. The method of analysis is the same as used by the U.S. Geological Survey in other areas (Dalrymple, 1960). The conclusions drawn from the analyses are derived from the rather limited amount of available streamflow data, which were adjusted for frequency calculation purposes to those collected at other gaging stations in the general area during the 46-year period 1912-57. The flood-frequency data are presented by graphs in figures 81 and 82; these data are shown also in table 52. In figure 81 the graph sets forth the average recurrence interval at which a flood of given magnitude may be equaled or exceeded. For example, the Dewatto Creek near Dewatto flood of November 3, 1955, which had a peak discharge of 2,110 cubic feet per second, can be expected to be equaled or exceeded on an average of once in about 25 years. In figure 82, the flood-frequency data presented in figure 81 have been converted to probability of occurrence. Instead of showing the magnitude of a flood in terms of average recurrence interval, it is shown in chance of occurrence in any one year. For example, the graph in figure 82, for Dewatto Creek near Dewatto, shows that the flood of November 1955 has a chance of about 4 percent of occurring in any one year.

Estimates of flood frequency are based on the assumption that events of the future will have the same average frequency as events that were experienced in the past. It is well to note, however, that although the probable average frequency of a flood of given size can be estimated, the time (year) of its next occurrence cannot be predicted. For example, a flood of 50-year magnitude may be expected to occur twice in 100 years, but it is possible for two such floods to occur in consecutive years or in the same year. Therefore, flood-frequency data can be used as a guide in the design of flood-control projects such as dikes, levees, and storage dams; and in the design of bridge and culvert openings, but cannot be used to forecast the time when a flood will occur.

WATER DEVELOPMENT SITES

The greatest need for water development in the report area lies in providing adequate storage for domestic and irrigation use in both rural and municipal areas during the summer deficit period. A steadily increasing population influx, resulting primarily from the recreational attractiveness of this area, has recently generated a corresponding increase in water demand. In certain critical areas most of the readily accessible supplies have been appropriated and, if the general trend continues, it will soon be necessary to find and develop more remote sources. The problem is further aggravated by a seasonal population fluctuation. Many people seeking recreation visit the area only during the summer months, thereby increasing the demand for domestic water when the supply is at a minimum.

Table 51. MOMENTARY ANNUAL MAXIMUM DISCHARGE, IN CUBIC FEET PER SECOND, OF UNION RIVER NEAR BELFAIR (0635), TAHUYA RIVER NEAR BELFAIR (0675), AND DEWATTO CREEK NEAR DEWATTO (0685).

UNION RIVER NEAR BELFAIR			TAHUYA RIVER NEAR BELFAIR			DEWATTO CREEK NEAR DEWATTO		
Water year	Discharge (cfs)	Date	Water year	Discharge (cfs)	Date	Water year	Discharge (cfs)	Date
1946	-		1946	428	Apr. 11, 1946	1946	-	
1947	-		1947	622	Feb. 14, 1947	1947		
1948	1,090	Oct. 19, 1947	1948	544	Oct. 19, 1947	1948	660	Oct. 19, 1947
1949	1,610	Feb. 22, 1949	1949	900	Feb. 22, 1949	1949	1,430	Feb. 22, 1949
1950	1,160	Jan. 21, 1950	1950			1950	1,630	Nov. 27, 1949
1951	1,230	Feb. 9, 1951	1951	780	Feb. 9, 1951	1951	1,160	Feb. 9, 1951
1952	616	Jan. 30, 1952	1952	642	Jan. 30, 1952	1952	968	Jan. 30, 1952
1953	702	Jan. 3, 1953	1953	616	Jan. 8, 1953	1953	680	Jan. 3, 1953
1954	834	Jan. 5, 1954	1954	845	Jan. 5, 1954	1954	1,280	Jan. 5, 1954
1955	665	Nov. 19, 1954	1955	794	Nov. 19, 1954	1955	-	
1956	1,040	Nov. 3, 1955	1956	1,210	Nov. 3, 1955	1956	2,110	Nov. 3, 1955
1957	788	Dec. 9, 1956	1957	-	-	1957	-	
1958	340	Dec. 25, 1957	1958	-	-	1958		
1959	499	Apr. 30, 1959	1959	-	-	1959	650	Jan. 24, 1959
1960	-	-	1960	-	-	1960	1,060	Nov. 20, 1959

Figure 80. ANNUAL MAXIMUM DISCHARGE OF UNION RIVER NEAR BELFAIR (0635), TAHUYA RIVER NEAR BELFAIR (0675), AND DEWATTO CREEK NEAR DEWATTO (0685).

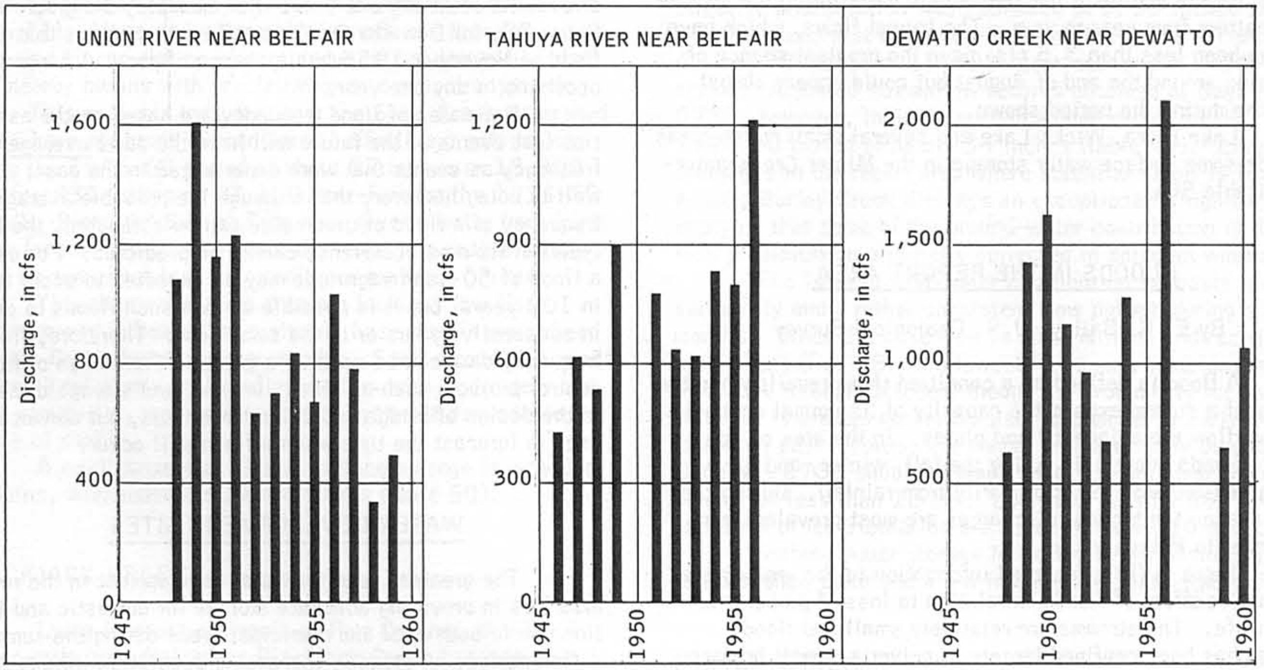

Figure 81. MAGNITUDE AND RECURRENCE INTERVAL OF ANNUAL FLOODS; UNION RIVER NEAR BELFAIR (0635), TAHUYA RIVER NEAR BELFAIR (0675), AND DEWATTO CREEK NEAR DEWATTO (0685).

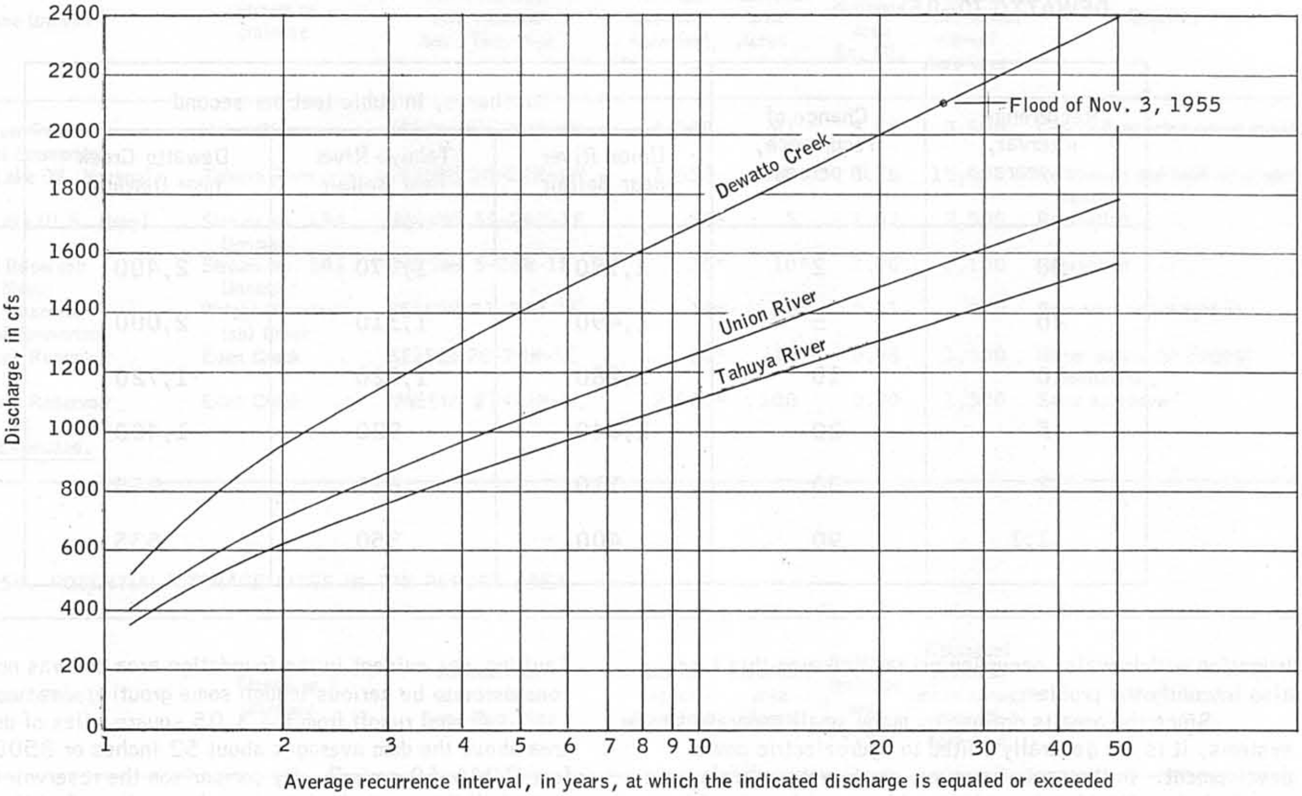

Figure 82. MAGNITUDE AND PERCENT CHANCE OF ANNUAL FLOODS; UNION RIVER NEAR BELFAIR (0635), TAHUYA RIVER NEAR BELFAIR (0675), AND DEWATTO CREEK NEAR DEWATTO (0685).

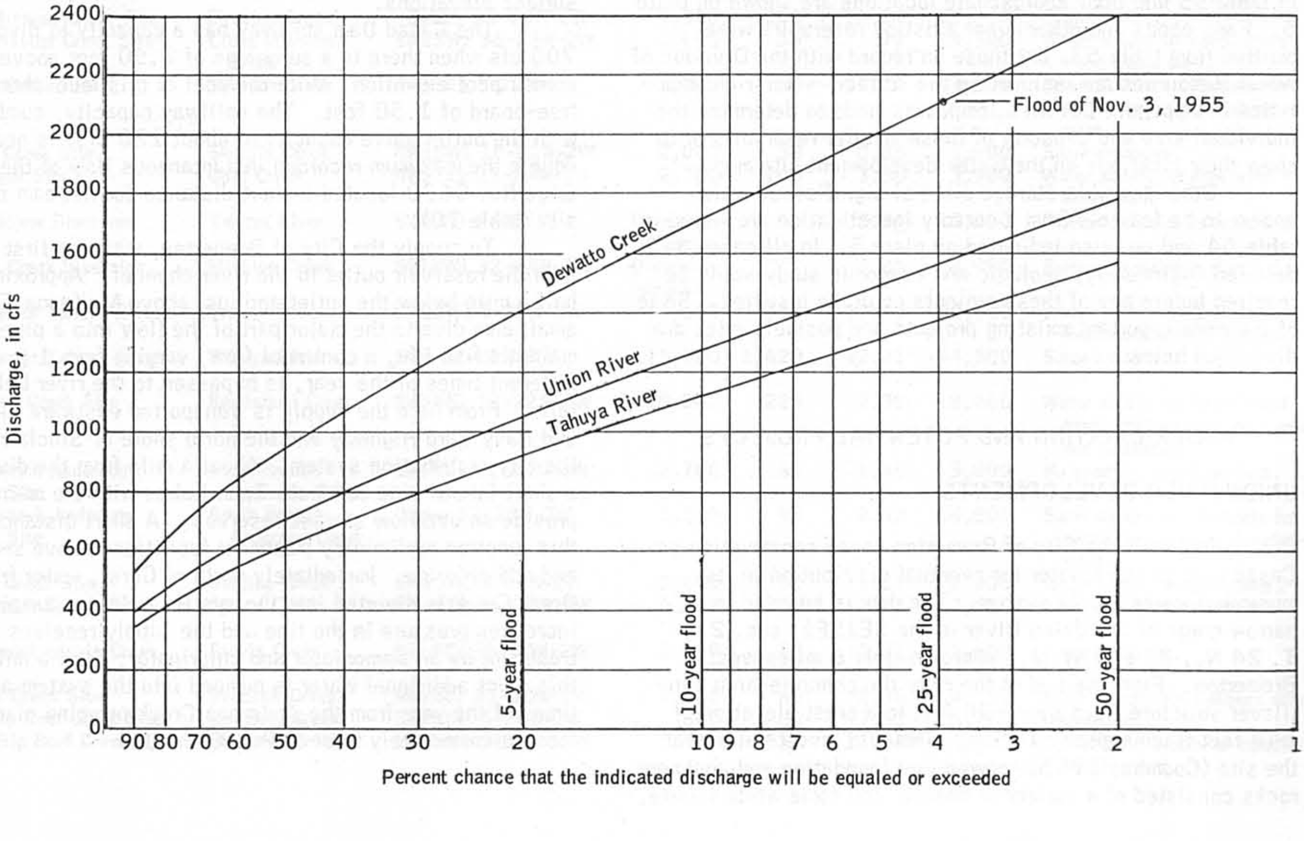

Table 52. AVERAGE RECURRENCE INTERVAL AND PERCENT CHANCE THAT SPECIFIC DISCHARGES WILL BE EQUALED OR EXCEEDED FOR UNION RIVER NEAR BELFAIR (0635), TAHUYA RIVER NEAR BELFAIR (0675), AND DEWATTO CREEK NEAR DEWATTO (0685).

Recurrence interval, in years	Chance of recurrence, in percent	Discharge, in cubic feet per second		
		Union River near Belfair	Tahuya River near Belfair	Dewatto Creek near Dewatto
50	2	1,780	1,570	2,400
20	5	1,490	1,310	2,000
10	10	1,280	1,120	1,720
5	20	1,040	920	1,400
2	50	710	625	955
1.1	90	400	350	535

Irrigation withdrawals, occurring primarily during this time, also intensify the problem.

Since the area is drained by many small separate stream systems, it is not generally suited to hydroelectric power development. In the past, however, small water wheels were operated at various locations to provide power for sawmill operations.

All major existing water development projects are listed in table 53 and their approximate locations are shown on plate 5. Farm ponds and other minor existing reservoirs were omitted from table 53, but those on record with the Division of Water Resources are included in the surface-water-right tabulation in Appendix D. No attempt was made to determine the individual size and capacity of these smaller reservoirs or to show their locations on the water-development site map.

Other possible storage sites of significance which appear to be feasible from a cursory investigation are listed in table 54 and are also indicated on plate 5. In all cases a detailed engineering, geologic and economic study would be required before any of these projects could be justified. Some of the more important existing projects and possible sites are discussed below.

MAJOR EXISTING AND POTENTIAL PROJECTS

UNION RIVER DEVELOPMENTS

In 1955 the City of Bremerton began construction on Casad Dam to store water for eventual distribution in its municipal water supply system. The dam is situated in a narrow gorge of the Union River in the SE¼SE¼, sec. 27, T. 24 N., R. 1 W.W.M., approximately 6 miles west of Bremerton. From the bed of the river the concrete-arch cantilever structure rises over 130 feet to a crest elevation of 644 feet (Cunningham, 1955). Geologic investigations at the site (Coombs, 1955) showed that foundation and abutment rocks consisted of a variety of basalts and some white felsite. Faulting was evident in the foundation area but was not considered to be serious though some grouting was necessary.

Annual runoff from the 3.05 square miles of drainage area above the dam averages about 52 inches or 8500 acre-feet (1946-60 period). By comparison the reservoir holds about half this amount at its normal operating elevation of 640 feet (1,300,000 gallons or 4000 acre-feet). Figure 83 shows the reservoir area and capacity at all possible water surface elevations.

The Casad Dam spillway has a capacity to discharge 700 cfs when there is a surcharge of 2.50 feet above the normal pool elevation. With the pool at this level there is a free-board of 1.50 feet. The spillway capacity, combined with the outlet valve capacity of about 120 cfs, is nearly double the maximum recorded instantaneous flow of the river at Gage No. 0630 located a short distance downstream from the site (table 10).

To supply the City of Bremerton, water is first released from the reservoir outlet to the river channel. Approximately half a mile below the outlet and just above McKenna Falls, a small dam diverts the major part of the flow into a pipeline. To maintain fish life, a continual flow, varying from 1 to 3 cfs at different times of the year, is bypassed to the river below the falls. From here the supply is transported eastward along the Old Navy Yard Highway and the north shore of Sinclair Inlet to the city distribution system. About a mile from the diversion a short lateral pipe connects Twin Lakes with the main line to provide an overflow storage reservoir. A short distance below this junction preliminary treatment facilities remove sediment and add chlorine. Immediately north of Gorst, water from Gorst Creek is diverted into the system. Here a pumping plant increases pressure in the line and the supply receives further treatment by an ammoniator and chlorinator. Half a mile below this point additional water is pumped into the system at certain times of the year from the Anderson Creek pumping plant located immediately west of Port Orchard.

Table 53. EXISTING MAJOR WATER DEVELOPMENT PROJECTS IN THE REPORT AREA.

Name (owner)	Stream or drainage	Approximate dam location Sec. Twp. Rge	Storage capacity Acre-feet	Inundated area Acres	Tributary drainage area Sq. Mi.	Estimated potential mean annual run-off Acre-feet	Remarks
Union River Reservoir (City of Bremerton)	Union River	SE¼SE¼ 27-24N-1W	4,000	91	3.05	8,500	City of Bremerton water supply
Tahuya Lake (W. Hobson)	Tahuya River	SE¼NW¼ 20-24N-1W	1,650	160	5.76	15,400	Recreation and land development
Bangor Lake (U.S. Navy)	Stream No. 134 Unnamed	NW¼NW¼ 19-26N-1E	50*	5	2.07	2,500	Recreation
Unnamed Reservoir (U.S. Navy)	Stream No. 141 Unnamed	SW¼SW¼ 5-26N-1E	70*	10*	1.90	2,100	Recreation
Unnamed Reservoir (City of Bremerton)	Wright (Charleston) Creek	SE¼SW¼ 21-24N-1E	15*	2	0.41	700	Bremerton water system
Eden Creek Reservoir	Eden Creek	SE¼SE¼ 20-20N-1E	80*	10	0.98	1,400	Water supply for Federal penitentiary
Butterworth Reservoir	Eden Creek	NW¼SW¼ 21-20N-1E	2,000*	100	0.90	1,300	Same as above

*Estimated.

Table 54. POTENTIAL STORAGE SITES IN THE REPORT AREA.

Name (owner)	Stream or drainage	Approximate dam location Sec. Twp. Rge	Storage capacity Acre-feet	Inundated area Acres	Tributary drainage area Sq. Mi.	Estimated potential mean annual run-off Acre-feet	Remarks
KITSAP PENINSULA							
Upper Mission Creek Site	Mission Creek	NE¼NE¼ 25-23N-2W	1,200	50	11.42	22,600	Water supply for north shore Hood Canal, east end.
Lower Mission Creek Site	Mission Creek	SE¼NE¼ 25-23N-2W	9,500	220	12.04	23,800	Same as above.
Little Mission Creek Site	Little Mission Creek	SW¼SW¼ 36-23N-2W	1,600	30	1.72	3,300	Water supply for north shore Hood Canal area.
Stimson Creek Site	Stimson Creek	NW¼SE¼ 3-22N-2W	5,100	85	1.72	3,500	Same as above. Suitable for partial or complete development.
Shoofly Creek Site	Shoofly Creek	NW¼SW¼ 18-22N-2W	2,000	30	0.85	1,900	Same as above.
Gold Creek Site	Gold Creek	NW¼SE¼ 21-24N-1W	2,700	100	1.36	3,900	Water supply for area west of Bremerton.
Tahuya River Diversion	Tahuya River	SW¼ 20-24N-1W	Diversion structure		5.8±	15,400	Bremerton water system.
Mission Creek Diversion	Mission Creek	NE¼NW¼ 32-24N-1W	Diversion structure		1.8±	4,900	Bremerton water system.
Small Lower Tahuya River Site	Tahuya River	NW¼SW¼ 5-22N-2W	11,100	340	37.70	84,000	Water supply for Tahuya Peninsula and recreation.
Large Lower Tahuya River Site	Tahuya River	SW¼ 12-22N-3W	111,700	1,620	42.21	94,300	Same as above.
Rendsland Creek Site	Rendsland Creek	SW¼NE¼ 17-22N-3W	10,200	225	7.39	18,400	Water supply for Great Bend area, east shore Hood Canal and recreation.
North Branch Anderson Creek Site	North Branch Anderson Creek	NE¼NE¼ 21-24N-2W	2,700	60	1.68	3,800	No specific use at present.
South Branch Anderson Creek Site	South Branch Anderson Creek	Center 21-24N-2W	5,500	95	2.03	4,800	Same as above. Suitable for partial or complete development.
Harding Creek Site	Harding Creek	SW¼SW¼ 9-24N-2W	2,600	50	1.27	2,900	Water supply and/or power.
East Branch Stavis Creek Site	Stavis Creek	NW¼SE¼ 36-25N-2W	6,200	110	3.28	7,000	No specific use at present.
West Branch Stavis Creek Site	Stavis Creek	SE¼SE¼ 35-25N-2W	1,700	40	1.71	3,600	Same as above.
Seabeck Creek Site	Seabeck Creek	NE¼NE¼ 31-25N-1W	1,800	40	2.30	4,400	Water supply for Seabeck area.
Upper Big Beef Creek Site	Big Beef Creek	SE¼NE¼ 5-24N-1W	800	80	7.62	16,700	Recreation.
Middle Big Beef Creek Site	Big Beef Creek	NE¼SW¼ 34-25N-1W	5,400	110	11.54	24,600	Suitable for partial or complete development.

Table 54. POTENTIAL STORAGE SITES IN THE REPORT AREA. (continued)

Name (owner)	Stream or drainage	Approximate dam location Sec. Twp. Rge	Storage capacity Acre-feet	Inundated area Acres	Tributary drainage area Sq. Mi.	Estimated potential mean annual run-off Acre-feet	Remarks
KITSAP PENINSULA (continued)							
Lower Big Beef Creek Site	Big Beef Creek	SE¼SW¼ 22-25N-1W	6,900	150	13.30	27,700	Suitable for partial or complete development. Water supply.
Anderson Creek Site	Anderson Creek	SW¼SW¼ 13-25N-1W	2,600	50	3.38	5,000	Same as above.
Jump-off Creek Site	Jump-off Creek	SW¼SE¼ 27-27N-1E	600	30	0.91	900	No specific use at present.
Hudson Creek Site	Hudson Creek	NE¼SW¼ 13-27N-1E	80	10	0.56	400	No specific use at present.
Gamble Creek Site	Gamble Creek	SW¼NW¼ 29-27N-2E	20,000	525	6.19	4,600	Recreation and irrigation.
Stream No. 201 Site	Stream No. 201 Unnamed	SW¼SW¼ 30-26N-2E	600	20	1.74	1,500	No specific use at present.
Stream No. 202 Site	Stream No. 202 Unnamed	SW¼NE¼ 25-26N-1E	320	15	1.35	1,300	Same as above.
Upper Scandia Creek Site	Scandia Creek	NE¼NW¼ 34-26N-1E	140	10	2.12	2,300	Same as above.
Lower Scandia Creek Site	Scandia Creek	NE¼SW¼ 27-26N-1E	80	7	2.18	2,400	Same as above.
Little Scandia Creek Site	Little Scandia Creek	NW¼NE¼ 34-26N-1E	80	7	0.37	400	Same as above.
North Branch Steele Creek Site	North Branch Steele Creek	SE¼SE¼ 14-25N-1E	60	8	2.81	3,000	Same as above.
South Branch Steele Creek Site	South Branch Steele Creek	SW¼NE¼ 23-25N-1E	230	20	1.71	2,100	Same as above.
Mosher Creek Site	Mosher Creek	NE¼SW¼ 34-25N-1E	70	7	1.57	1,900	Same as above.
Barker Creek Site	Barker Creek	NW¼SW¼ 22-25N-1E	130	15	3.71	4,200	Same as above.
West Branch Clear Creek Site	West Branch Clear Creek	NE¼SE¼ 8-25N-1E	2,000	75	3.44	4,200	Recreation and water supply.
Kochs Creek Site	Kochs Creek	NE¼SW¼ 17-25N-1E	60	6	2.04	2,700	No specific use at present.
Wildcat Creek Site	Wildcat Creek	NW¼NE¼ 12-24N-1W	1,400	40	5.75	10,200	Water supply Chico area. Suitable for partial or complete development.
Upper Lost Creek Site	Lost Creek	SW¼SW¼ 12-24N-1W	2,000	40	2.19	5,200	Same as above.
Lower Lost Creek Site	Lost Creek	SE¼NE¼ 12-24N-1W	1,700	40	2.93	6,800	Same as above.
Parish Creek Site	Parish Creek	SW¼SW¼ 32-24N-1E	2,000	40	1.53	2,800	Water supply for Gorst area. Suitable for partial or complete development.
Ross Creek Site	Ross Creek	SW¼NE¼ 34-24N-1E	700	30	2.02	3,200	Water supply Port Orchard.
Upper Blackjack Creek Site	Blackjack Creek	NE¼NE¼ 22-23N-1E	350	15	2.66	4,500	Irrigation.
Lower Blackjack Creek Site	Blackjack Creek	SE¼NE¼ 35-24N-1E	1,700	45	12.13	19,400	No specific use at present.
Stream No. 281 Site	Stream No. 281 Unnamed	SE¼NW¼ 25-24N-1E	130	7	0.48	700	No specific use at present.
Beaver Creek Site	Beaver Creek	SW¼NW¼ 21-24N-2E	1,000	25	1.19	1,500	Same as above.
Stream No. 294-1 Site	Stream No. 294 -1 Unnamed tributary to Curley Creek	SW¼NE¼ 4-23N-2E	190	6	0.77	1,100	Same as above.
Stream No. 298 Site	Stream No. 298 Unnamed	NW¼NE¼ 3-23N-2E	210	8	0.37	480	Water supply for Harper area.
Stream No. 329 Site	Stream No. 329 Unnamed	SW¼NE¼ 13-21N-1E	600	30	1.57	2,200	No specific use at present.
Warren Creek Site	Warren Creek	SW¼SE¼ 22-21N-1E	190	15	0.85	1,200	Water supply for Warren area.
Minter Creek Site	Minter Creek	SW¼SE¼ 9-22N-1E	2,800	120	4.43	7,800	Recreation.
Lackey Creek Site	Lackey Creek	SE¼NW¼ 31-22N-1E	160	15	2.18	3,600	No specific use at present.
Stream No. 400 Site	Stream No. 400 Unnamed	SW¼SE¼ 28-21N-1W	350	15	1.37	2,200	Water supply for Herron area.
Fern Lake Site	Rocky Creek	NW¼NW¼ 16-22N-1W	2,400	130	3.99	7,000	Enlarge Lake for recreation.
Rocky Creek Site	Rocky Creek	NE¼NE¼ 27-22N-1W	1,300	50	18.08	31,900	No specific use at present.
Coulter Creek Site	Coulter Creek	SW¼NW¼ 25-23N-1W	380	25	3.97	74,100	No specific use at present.
Stream No. 425-7 Site	Stream No. 425 -7 Unnamed tributary to Coulter Creek	SE¼NW¼ 34-23N-1W	320	15	0.72	1,300	Same as above.
Stream No. 425-4 Site	Stream No. 425 -4 Unnamed tributary to Coulter Creek	NW¼NE¼ 33-23N-1W	290	15	1.54	2,800	Same as above.
Stream No. 425-3 Site	Stream No. 425 -3 Unnamed tributary to Coulter Creek	NW¼NW¼ 10-22N-1W	150	6	0.63	1,100	Water supply for North Bay area.

Table 54. POTENTIAL STORAGE SITES IN THE REPORT AREA. (continued)

Name (owner)	Stream or drainage	Approximate dam location Sec. Twp. Rge	Storage capacity Acre-feet	Inundated area Acres	Tributary drainage area Sq. Mi.	Estimated potential mean annual run-off Acre-feet	Remarks
BAINBRIDGE ISLAND							
Port Madison Creek Site	Port Madison Creek	NW¼SE¼ 2-25N-2E	45	3	0.61	450	No specific use at present.
Stream No. 434 Site	Stream No. 434 Unnamed	NE¼SE¼ 15-25N-2E	260	25	1.46	1,800	Same as above.
Stream No. 437 Site	Stream No. 437 Unnamed	NW¼SW¼ 26-25N-2E	120	6	0.53	480	Water supply Winslow area.
Stream No. 442 Site	Stream No. 442 Unnamed	NE¼SW¼ 35-25N-2E	15	2	0.48	490	Water supply Eagledale area.
VASHON AND MAURY ISLANDS							
Stream No. 481 Site	Stream No. 481 Unnamed	NE¼SE¼ 5-22N-3E	550	15	0.88	1,000	Water supply for Chautaugua area. Other sites possible.
Stream No. 482 Site	Stream No. 482 Unnamed	SW¼SE¼ 5-22N-3E	130	6	0.40	450	Water supply for Ellisport area.
Tahlequah Creek Site	Tahlequah Creek	NE¼SE¼ 2-21N-2E	200	9	1.13	1,400	Water supply for Tahlequah area. Other sites possible.
Needle Creek Site	Needle Creek	NW¼NW¼ 19-23N-2E	2,800	70	2.47	2,900	Water supply for Colvos-Cedarhurst area. Other sites possible. Suitable for partial or complete development.

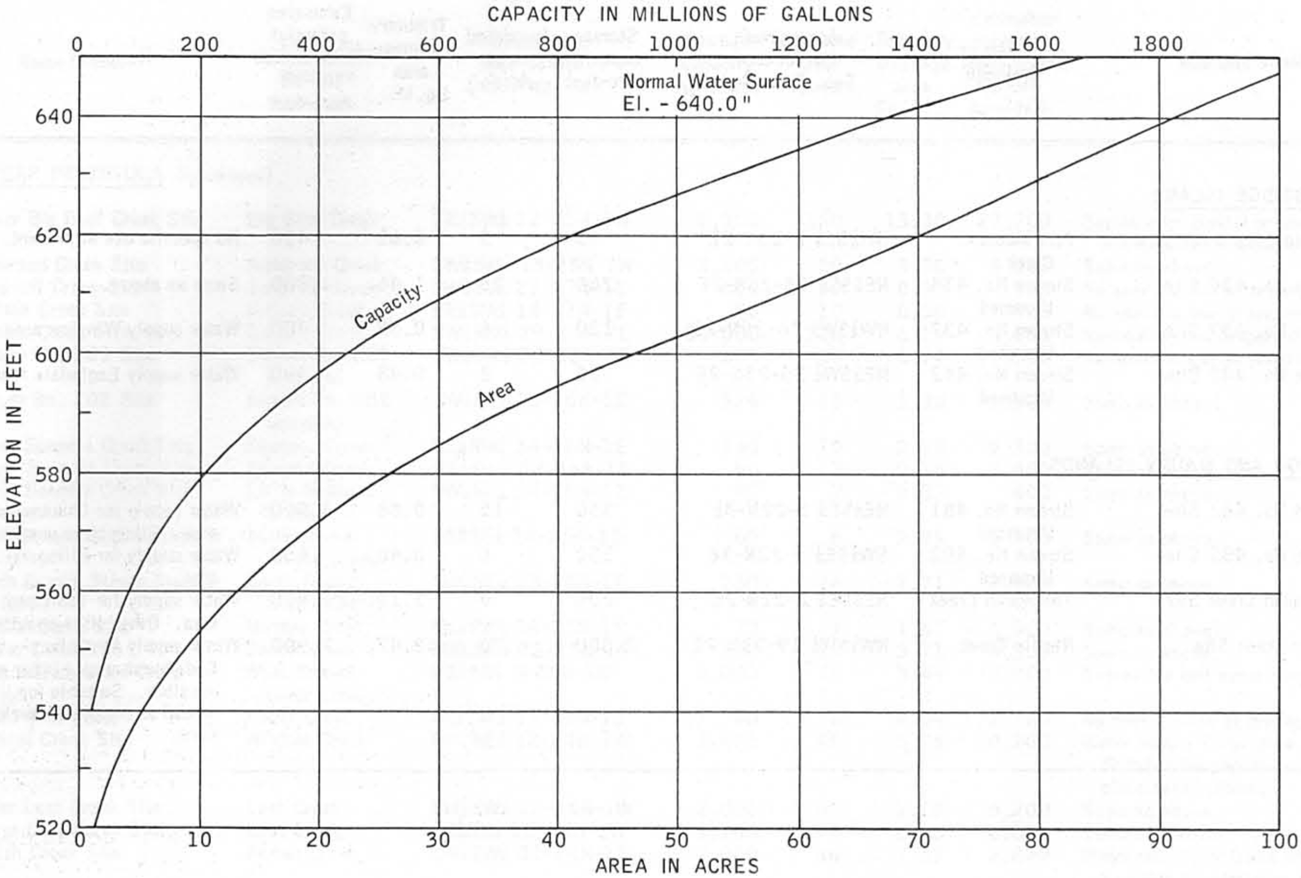

Figure 83. RESERVOIR AREA AND CAPACITY CURVES, UNION RIVER RESERVOIR

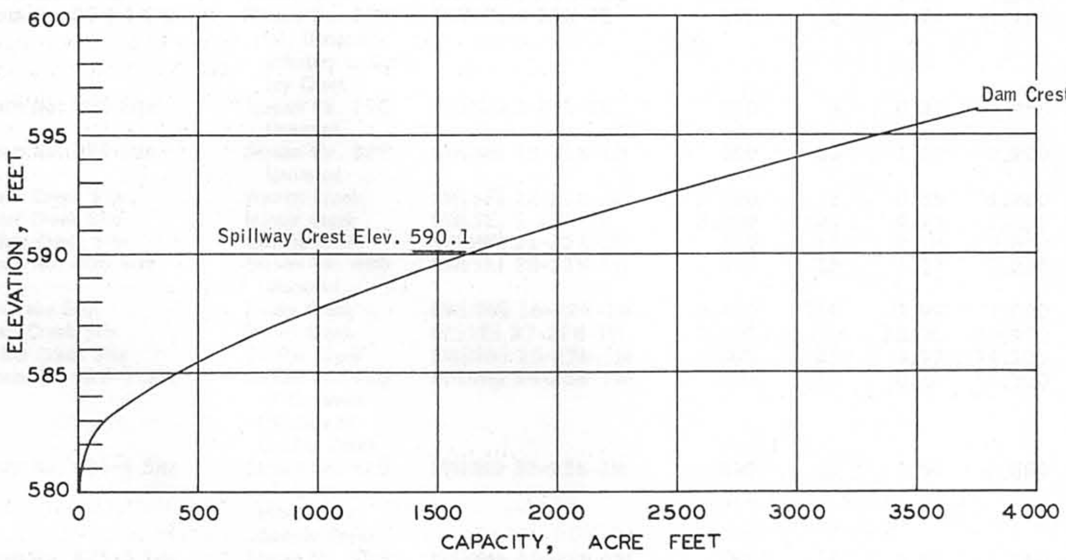

Figure 84. RESERVOIR CAPACITY CURVE, TAHUYA LAKE.

GOLD CREEK SITE

Kitsap County Public Utility District No. 1 has proposed the construction of a dam and reservoir on upper Gold Creek to provide a water supply system for the area immediately west of Bremerton. The site is located approximately one-quarter of a mile upstream from gaging station No. 0655 in the narrowest part of the gap between Green and Gold Mountains. A preliminary engineering report (Beck, 1960) showed that a dam at this location would impound runoff from approximately 1.36 square miles, and with a normal pool elevation at 808 feet, would have a capacity to store 2,700 acre-feet of water. By comparison the drainage area actually produces a mean annual runoff of 54 inches or about 3900 acre-feet (1946-60 period). The proposed reservoir capacity would provide a constant usable supply of about 2.4 million gallons per day which allows for approximately 1100 acre-feet of dead storage and a continual minimum release of 0.3 cfs to sustain downstream fish life.

A superficial investigation of the site indicated that a good foundation of basalt bedrock lies close to the existing surface. This underlying formation appears to be quite watertight so seepage losses from the storage area would probably be negligible. The preliminary design study further indicated that the dam would need about 100,000 cubic yards of earth fill and would use a spillway capable of passing 1100 cfs. This capacity would be more than five times the recorded maximum instantaneous flow at Gage No. 0655 (table 10).

Two pipeline routes are possible to deliver the supply to the service area. One would follow Lost Creek and terminate near the north end of Kitsap Lake. The other, a shorter route, would run about due east from the reservoir to the south end of Kitsap Lake. Both routes would require some initial pumping to lift the supply about 80 feet from the reservoir to the watershed divide. The water would then flow by gravity to the area of distribution. To handle peak demand flows, the transmission line would be designed to have a capacity of 6 million gallons per day.

TAHUYA LAKE PROJECT

In 1961 a dam was constructed on the Tahuya River a short distance below the confluence of Gold Creek to deepen and enlarge Lake Tahuya for purposes of land development and recreation. Located in the SE¼NW¼ sec. 20, T. 24 N., R. 1 W.W.M., this earth-fill structure is seated on basalt bedrock and is flanked by compacted layers of glacial till. Rising about 25 feet above the bed of the river to an elevation of 596 feet, the dam creates a backwater of nearly a mile and impounds about 1650 acre-feet at the elevation of the spillway crest (590.1 feet). Figure 84 shows the reservoir capacity at other elevations up to the top of the dam. The reservoir, thus created, eliminated most of the swamp and marsh area that surrounded the original lake and provided about three miles of improved shoreline for lake-shore property development.

A drainage area of 5.76 square miles contributes a mean annual runoff of about 50 inches or 15,400 acre-feet to this reservoir. The maximum recorded instantaneous discharge of the river at Gage No. 0660, located about three-quarters of a mile downstream from the site, was 504 cfs on November 3, 1955. To handle future floods, the structure employs a concrete overflow spillway capable of discharging 700 cfs under a head of 4.15 feet above the normal lake level. A fish ladder is also incorporated in the spillway structure to allow for passage of anadromous fish. This fishway and an outlet pipe permits the structure to pass an additional 100 cfs. Since none of the stored water is diverted or used consumptively, outflow from the reservoir is at all times equal to the natural inflow, minus any change in storage and minus any intervening losses through evaporation or seepage.

In 1950 the City of Bremerton filed an application with the Division of Water Resources to divert up to 20 cfs from this same general location on the Tahuya River to augment their existing municipal supply. Under the proposed plans, waters from the Tahuya River and up to 5 cfs from Mission Creek would be piped to existing facilities at Twin Lakes. Quality problems and recent developments, however, make the feasibility of such a project somewhat questionable, and it is doubtful whether it will ever be constructed.

LOWER TAHUYA RIVER SITES

From a superficial examination, two reservoir sites along the lower reaches of the Tahuya River appear to be feasible. The smaller of the two projects would involve construction of a dam across a narrow constriction of the river channel where it crosses the west line of sec. 5, T. 22 N., R. 2 W.W.M. At this location it appears that a dam, 70 feet high and 700 feet long at the crest, could impound water to an elevation of about 200 feet. Water impounded to that elevation would create a lake 2.5 miles long with a surface area of 0.53 square miles and a volume of about 11,100 acre-feet. The project would receive runoff from a 37.7 square-mile drainage area which in the mean has a potential to contribute about 42 inches or 84,000 acre-feet per year (1946-60 period).

For the larger development, a dam would be constructed across the river in the SW¼ sec. 12, T. 22 N., R. 3 W.W.M., near the location of stream Gage No. 0680. Though this site would require a larger dam, the higher cost might be offset by greater benefits from the increased storage capacity. Topography in the abutment areas indicates that it might be feasible to impound water to an elevation as high as 240 feet. To maintain water at this level would require a dam approximately 200 feet high and about 2,000 feet long at its crest. Such a structure would create a 6 mile long lake with a surface area of about 2.54 square miles. This artificial lake would completely inundate the reservoir area of the smaller project and would have a storage capacity of about 111,700 acre-feet. Potential mean annual runoff from the 42.2 square miles of drainage area above this site amounts to 42 inches or 94,300 acre-feet so, in an average year, inflow to the reservoir would be adequate to replace about 85 percent of the total capacity.

If detailed geologic and engineering studies showed either of the sites to be structurally feasible, and if economic considerations proved such a development to be sound, it would be necessary to establish the final size of either project according to maximum derivable benefits.

GAMBLE CREEK SITE

Assuming geologic conditions are favorable, the topography indicates that a sizable reservoir could be created along the lower reaches of Gamble Creek. The most probable dam site is located in the NW¼ sec. 29, T. 27 N., R. 2 E.W.M., at a point where the stream passes through a narrow gap about one half a mile above its mouth. Here a dam 80 feet high and about 600 feet long could impound water to an elevation of 120 feet and create a lake with a surface area of approximately 0.82 square mile. A reservoir of this size, having a capacity of nearly 20,000 acre-feet, would represent the maximum possible development of this site, but it would not necessarily be the most economical. The 6.19 square-mile drainage area tributary to the site produces a mean annual potential runoff of only 14 inches or about 4600 acre-feet (1946-60 period); consequently, it is probable that it would take more than 4 years to initially fill the reservoir. Excessive loss through evaporation from this large surface area also might tend to make the maximum development undesirable.

A more practical development might be obtained by limiting the reservoir elevation to about 80 feet. At this level the artificial lake would occupy only half as much area and would store about 3900 acre-feet which could normally be replaced each year. The smaller project, however, would probably be limited to recreation and irrigation use, since the maximum depth of the lake would be only about 20 feet making it undesirable for a domestic water supply reservoir. Whatever size the project might be, a few buildings lying in the reservoir area would have to be condemned and 2 to 3 miles of highway relocated.

WATER QUALITY

By A. S. Van Denburgh*

GENERAL

All natural water contains dissolved material. The quantity of dissolved material in water ranges from about 0.001 percent for rainwater to about 30 percent for highly concentrated brines. Through experience man has learned that many water uses--private, agricultural, and industrial--place certain limits on the allowable concentration of various dissolved constituents in water. The State's water supply must therefore be monitored, not only to determine the concentration of dissolved organic and inorganic material but also to aid in the protection of future quality.

The survey of the chemical and physical qualities of both ground and surface waters of the Kitsap Peninsula and certain adjacent islands was a cooperative project by the Washington State Division of Water Resources and the United States Geological Survey. Because little basic data were available before the project's start, an intensive program of water-quality data collection was necessary. This program involved sampling and later resampling of 19 streams and one lake. In addition, 39 ground-water sources (38 wells and one spring) were sampled. Compilations of the chemical and physical data for the surface and ground waters, along with interpretation of these data, appear on the following pages.

EXPRESSION OF WATER-QUALITY DATA

The analyses in tables 55 and 56 show the concentration of as many as 19 constituents or properties of each water sample. Chemical constituents, dissolved solids, and hardness of water are reported in parts per million (ppm). A part per million is a unit weight of a constituent in a million unit weights of water.

Iron concentrations are assumed to represent iron in solution at the time of sample collection, unless they are termed "total iron". The term "total iron" applies to iron concentrations in samples that are turbid or that contain sediment at the time of collection. The distinction is made because both the material forming the turbid suspension and the sediment can contain iron which contributes to the reported iron value.

Either of two methods is used to determine the dissolved-solids content of a water sample. The determined constituents are added together or a known volume of sample is evaporated and weighed. Determinations made by the two methods usually differ by less than 10 percent. However, in some water the high content of organic or colloidal material or appreciable quantities of certain inorganic constituents will produce a significant numerical difference between these two expressions of dissolved material. Only the calculated values (sum of determined constituents) for dissolved-solids contents will be referred to in this report unless otherwise noted.

The hardness-of-water determination involves measurement of the combined concentrations of calcium and magnesium. These two constituents are the ones primarily responsible for hardness, a characteristic that is indicated by the deposition of calcium compounds in hot water lines and other heat exchange equipment and by excessive soap consumption. Hardness data are reported as the calcium carbonate equivalent of the concentration of calcium plus magnesium.

Several properties of water are not expressed in parts per million units. Specific conductance, for example, is expressed in micromhos at 25°C. This determination is simply the measure of how readily an electric current will pass through water. In general the greater the amount of dissolved material in the water the more readily an electric current will pass through it. Specific conductance is thus a rough measure of the amount of dissolved material in water. Numerically, the dissolved-solids content of water usually is about two-thirds to three-fourths of the specific conductance value. The pH of water, a measure of its acidity or alkalinity, is expressed in terms of pH units, which express the negative logarithm of hydrogen-ion (H^+) concentration. The color of a water is based on comparison with a standard color intensity scale and is reported in color units.

WATER QUALITY STANDARDS

Many mandatory and recommended standards have been established for drinking water as well as for water utilized in specific industrial applications. The revised drinking water standards of the U. S. Public Health Service (1962) are shown in Tables 57 and 58. These limits in general have been adopted throughout the United States as standards of drinking water quality. In 1950 the American Water Works Association published a compilation of water quality tolerances for various industrial applications. A part of this compilation is shown in Table 59. The data are useful in predicting the suitability of a specific water supply for a specific industrial application.

No universally used classification of the degree of water hardness is available, because the requirements for different industrial applications vary so widely (see Table 59). However, water having less than 60 ppm of hardness is generally considered to be soft, whereas a value between 61 and 120 ppm indicates moderate hardness. Water in the 61 to 120 ppm range is still suitable for many purposes without treatment. However, if hardness exceeds 120 ppm, softening is profitable for some uses, and if hardness is greater than 180 ppm the water is considered very hard, and it requires treatment for almost all purposes.

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Table 55. ANALYSES OF GROUND-WATER SAMPLES FROM THE KITSAP PENINSULA AND ADJACENT ISLANDS, WASHINGTON (analyses by the U. S. Geological Survey).

Sampling site number	Well number	Owner	Approx. altitude above sea level (in feet)	Well depth (in feet)	Depth of water-bearing interval (in feet)	Geologic source of ground water a/	Sample collection date	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
1	20/1W-11C	Peninsula School District No. 401	220	224	198-224	Qc	3/1/61	49	32	0.26	7.5	6.5	4.5
2	20/1W-24F	John Conboy	75	285	70-180	Qss?	3/1/61	49	41	0.13	30	7.6	10
3	21/1W-2C	Peninsula School District No. 401	50	158	82-88	Qc	3/1/61	49	28	0.02 b/	11	5.9	5.5
4	21/1-35D	Shorewood Beach Water Company	25	432	358-378	Below Qss	3/1/61	51	41	0.62	21	15	10
6	21/2-1L	R. K. Beymer	300	180	170-180	Qc	3/3/61	47	38	0.48	5.5	5.6	5.0
5	21/2-8C	Gig Harbor Water Department	60	375	73-75	Qss	3/2/61	50	34	0.22	12	6.9	5.5
7	22/2W-1C	Terra Linda Auto Court	15	42	?	Above Qc	3/2/61	50	21	0.02	9.0	3.6	3.0
8	22/3W-26Q	R. J. Folmer	10	55	51-55	Above Qc ?	3/2/61 8/16/61	48 52	19 19	0.20 0.21 b/	11 31	4.4 13	22 60
9	22/1-1M2	E. P. Eberle	40	62	55-62	Qss	10/4/60 5/25/61	54 56	29 --	0.11 --	14 --	3.8 --	4.6 --
10	22/1-8H1	R. I. Mirador	305	100	80-100	Qc or above	3/1/61	48	20	0.05	6.0	2.9	3.0
11	22/1-12D2	K. Lake	25	353	343-353	Below Qss	10/4/60 5/25/61	50 51	38 --	0.09 --	12 --	1.5 --	19 --
12	22/1-12R2	A. Steiner	120	18	8-18	Above Qc	10/4/60 5/25/61	58 58	18 --	0.03 --	15 --	1.8 --	11 --
13	22/3-16F1	Queens City Broadcasting Co.	50	462	445-460	Below Qss	12/16/59 7/5/60	54 66	41 --	1.3 b/ --	45 --	19 --	43 --
14	23/2W-13H1	Wash. State Dept. of Institutions	400	180	170-180	Qc	5/23/61	48	24	0.04	10	4.4	3.1
15	23/1-7D	Sunnyslope Water Development Co.	470	219	102-119	Qc	3/2/61	40	25	0.01	9.0	4.5	3.7
16	23/1-10A1	C. Silvernail	215	184	174-184	Qc or Qss	2/28/61	50	24	0.01	10	7.1	4.3
17	23/1-26H2	W. J. Moffitt	190	90	55-70?	Qc	2/28/61	49	36	0.81 b/	8.0	7.1	3.7
18	23/2-2C3	J. P. Noble	?	?	?	Qss?	10/4/60 5/25/61	54 54	33 --	0.05 --	15 --	8.8 --	7.8 --
19	23/2-28K3	F. Eaton	340	98	?	Qc	3/2/61	45	24	0.01	6.5	3.9	3.6
20	23/3-29Q SPRING	King Co. Water District No. 19	125 ± 25	0	0	Qc	3/3/61	47	28	0.01 b/	10	8.6	6.0
21	24/1W-2G	J. J. Snapp	390	65	60-65?	Above Qc	2/28/61	--	20	0.16 b/	12	3.2	7.1
22	24/1W-7C1	W. Lewis	500	140	137-140	Qc	2/28/61	47	21	0.07	8.0	5.1	3.3
23	24/1W-29Q1	H. W. Blanchard	525	85	15-28	Above Qc	10/4/60 5/25/61	51 51	17 --	0.85 b/ --	22 --	1.5 --	7.9 --

a/ Geologic source determined by use of chemical and (or) geologic information. Qc and Qss are geologic symbols for the Colvos Sand and Salmon Springs(?) Drift.

b/ Total iron (concentrations not footnoted represent iron in solution at the time of sample collection).

Parts per million													
Potassium	Bicarbonate (HCO_3)	Carbonate	Sulfate	Chloride	Fluoride	Nitrate	Phosphate	Dissolved Solids: Calculated	Dissolved Solids: Residue on evap. at 180°C	Hardness (as $CaCO_3$)	Specific conductance (Micromhos at 25°C)	pH	Color
0.8	64	0	0.2	2.5	0.1	0.6	0.08	87	83	46	111	7.2	0
4.9	156	0	0.4	2.8	0.1	0.7	0.49	175	171	106	250	7.8	5
0.2	73	0	0.0	3.5	0.1	0.1	0.08	90	83	52	125	7.6	0
3.4	163	0	0.4	4.5	0.1	0.2	0.39	177	168	112	258	7.7	10
1.0	42	0	11	2.8	0.1	0.1	0.18	91	90	36	104	7.4	5
1.8	83	0	0.4	2.2	0.1	0.3	0.87	105	99	58	141	7.8	0
0.0	47	0	0.2	2.2	0.0	2.0	0.03	64	64	38	91	6.6	0
0.4	90	0	3.6	13	0.1	0.0	0.35	118	113	46	189	7.9	0
1.4	76	0	19	132	--	--	--	312	--	132	595	7.5	--
1.8	70	0	4.8	1.8	0.1	0.1	0.28	94	92	50	122	8.1	5
--	70	0	--	--	--	--	--	--	--	50	124	8.0	--
0.0	29	0	0.2	3.0	0.0	6.0	0.07	55	59	27	73	7.4	0
2.6	92	1	0.8	1.5	0.1	0.1	0.27	122	120	36	151	8.3	5
--	92	1	--	--	--	--	--	--	--	35	152	8.3	--
0.9	46	0	15	9.0	0.0	4.9	0.04	99	100	45	151	6.3	5
--	54	0	--	--	--	--	--	--	--	48	146	6.5	--
7.4	346	0	0.3	8.8	0.3	0.5	0.59	338	346	190	545	7.6	10
--	330	0	--	--	--	--	--	--	--	184	511	7.8	--
0.4	60	0	0.0	1.5	0.1	0.2	0.15	74	76	43	97	7.8	0
0.5	60	0	0.4	1.2	0.0	0.1	0.11	75	68	41	99	8.0	0
0.8	72	0	1.8	2.0	0.1	0.1	0.28	85	85	54	124	7.6	0
1.0	62	0	4.4	2.0	0.1	0.2	0.11	94	96	49	115	7.2	20
2.1	105	0	3.6	1.5	0.1	0.1	0.43	124	120	74	176	8.1	5
--	106	0	--	--	--	--	--	--	--	74	178	7.9	--
0.2	35	0	2.4	3.8	0.1	4.4	0.09	66	70	32	85	7.3	0
1.2	44	0	20	6.0	0.1	10	0.07	112	116	60	158	7.3	5
0.3	50	0	6.8	5.2	0.1	2.0	0.00	82	88	43	123	6.1	0
0.0	56	0	0.2	1.2	0.0	0.3	0.26	67	65	41	93	7.7	0
0.3	90	0	4.4	1.2	0.0	0.1	0.06	98	98	61	152	7.9	5
--	92	0	--	--	--	--	--	--	--	62	155	8.1	--

Table 55. ANALYSES OF GROUND-WATER SAMPLES FROM THE KITSAP PENINSULA AND ADJACENT ISLANDS, WASHINGTON (analyses by the U. S. Geological Survey). (Continued)

Sampling site number	Well number	Owner	Approx altitude above sea level (in feet)	Well depth (in feet)	Depth of water-bearing interval (in feet)	Geologic source of ground water a/	Sample collection date	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
24	24/1W-35P1	E. Logan	330	87-1/2	74-79	Above Qc	10/4/60	49	21	1.3 b/	7.0	2.7	2.8
							5/25/61	50	--	--	--	--	--
25	24/1-25M1	Town of Port Orchard Well 6	20	832	805-832	Qss	3/3/61	49	35	0.04	18	3.6	5.5
26	24/1-26N1	Wilkins Dist. Co.	20	197	88-190	Qss	10/4/60	47	36	0.05	18	3.2	5.1
							4/26/61	49	--	--	17	4.1	--
27	24/1-33K5	City of Bremerton Well 5	35	587	?	Qss	12/16/59	54	31	0.01	15	2.6	6.9
							6/3/60	54	--	--	--	--	--
28	24/2-33H1	W. L. Cheney	20	134	133-134	Qss	2/28/61	51	38	0.06	15	2.2	17
29	25/1-9G1	L. D. Fairfield	80	164	135-140	Qss	6/3/60	58	37	0.08	13	6.6	6.3
							10/5/60	54	--	--	--	--	--
30	25/1-23K	B. P. Bitle	190	69	?	Qc ?	2/28/61	47	20	3.3 b/	10	6.1	4.7
31	25/2-26K	D. W. Buchanan	120	175	171-175	Qss	2/1/61	50	35	0.45	18	5.8	5.6
32	25/2-35H3	Baxter-Wycoff Co.	10	813	90-105 &697-780	Qss and below	10/5/60	53	26	0.04 b/	20	12	18
							5/25/61	56	--	--	--	--	--
33	25/2-35M2	H. I. Foss	260	148	143-148	Qc	2/27/61	50	28	2.3 b/	11	12	7.5
34	26/1-13J1	E. Bowman	310	144	130-144	Qc	2/28/61	48	24	0.15	8.0	4.0	4.0
35	26/1-36P1	U. S. Navy	14	380	?	Qss	10/5/60	53	33	0.24	28	5.3	20
							5/25/61	55	--	--	--	--	--
36	26/2-10Q1	M. Calhoun	125	260	254-260	Qss	2/27/61	48	35	0.59	9.0	8.7	6.0
37	27/2-25N1	State of Wash.	5	298	266-272?	Qss?	2/27/61	52	39	0.15	14	9.2	16
38	27/2-28G1	E. C. Fall	165	134	128-134	Qc	2/27/61	47	28	0.27	7.5	6.4	4.5
39	28/2-35M2	E. D. Byer	150	107	103-107	Qc	2/27/61	49	31	0.04	15	11	7.6

a/ Geologic source determined by use of chemical and (or) geologic information. Qc and Qss are geologic symbols for the Colvos Sand and Salmon Springs(?) Drift.

b/ Total iron (concentrations not footnoted represent iron in solution at the time of sample collection).

Parts per million													
Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved Solids: Calculated	Dissolved Solids: Residue on evap. at 180°C	Hardness (as $CaCO_3$)	Specific conductance (Micromhos at 25°C)	pH	Color
0.4	34	0	0.8	2.5	0.0	4.0	0.02	58	60	29	74	7.0	5
--	46	0	--	--	--	--	--	--	--	35	87	7.2	--
1.4	81	2	1.2	1.2	0.0	0.1	0.34	108	105	60	142	8.4	0
1.3	79	0	3.6	1.8	0.1	0.3	0.35	109	108	58	137	8.0	5
--	79	1	--	--	--	--	--	--	--	59	138	8.4	--
1.7	69	2	3.4	1.5	0.3	0.0	0.38	99	101	48	129	8.3	0
--	70	2	--	--	--	--	--	--	--	48	133	8.4	--
2.0	95	2	0.0	4.8	0.1	0.1	0.91	129	119	46	168	8.5	5
3.0	88	0	0.4	2.5	0.1	0.5	1.1	114	108	60	145	7.7	5
--	89	0	--	--	--	--	--	--	--	59	148	7.9	--
0.4	65	0	3.2	2.2	0.0	1.4	0.08	80	81	50	121	6.8	5
2.0	91	0	4.0	2.8	0.2	0.3	0.39	120	113	69	159	7.3	10
2.0	154	0	6.6	5.2	0.1	0.1	0.19	166	164	100	264	8.2	0
--	154	0	--	--	--	--	--	--	--	100	263	8.2	--
0.6	89	0	5.8	6.0	0.1	5.3	0.11	120	114	77	184	7.4	10
0.4	34	0	0.2	6.2	0.0	10	0.11	74	70	36	101	7.5	0
1.9	129	0	0.4	22	0.1	3.4	2.0	180	182	92	274	7.6	5
--	130	0	--	--	--	--	2.1	--	--	92	266	7.8	--
2.0	72	0	7.0	4.8	0.1	0.2	0.24	109	103	58	146	7.4	5
3.2	126	0	0.0	5.5	0.1	0.1	0.82	150	149	73	213	8.1	5
0.8	56	0	5.6	2.0	0.1	0.5	0.16	84	85	44	110	7.8	5
2.5	86	0	15	8.2	0.1	0.9	0.26	134	128	82	200	7.9	0

Table 56. ANALYSES OF SURFACE WATER FROM THE KITSAP PENINSULA AND ADJACENT ISLANDS, WASHINGTON. (Analyses by the U. S. Geological Survey).

Sampling site number	Name of stream or lake	Sampling site location	Area of drainage basin upstream from sample site (square miles)	Sample collection date	Estimated streamflow (cubic feet per second)	Water temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
KP1	Union River	At McKenna Falls (24/1W-34G)	3.16a/	2/3/61	20-30	43	11	.16b/	6.5	1.5	1.6
				8/16/61	3-8	65	11	.22	8.5	2.3	2.0
KP2	Union River	1.5 mi. N of Belfair (23/1W-20G)	19.2 a/	2/1/61	75-100	44	--	--	5.0	1.6	--
				8/16/61	30-50	53	--	--	--	--	--
KP3	Tahuya Ck.	3 mi. NE of Tahuya (22/3W-13C?)	42.3	2/2/61	300-600	44	--	--	2.5	0.5	--
				8/16/61	10-15	58	--	--	--	--	--
KP4	Dewatto Ck.	2 mi. NE of Dewatto (23/3W-23F)	18.4	2/2/61	450 c/	43	7.9	0.10b/	3.0	0.4	1.0
				8/16/61	18 c/	--	18	--	8.0	3.2	2.4
KP5	Anderson Ck.	0.8 mi. NE of Holly (24/2W-17N)	5.58	2/2/61	50-75	44	--	--	3.0	0.8	--
				8/16/61	5-10	54	--	--	--	--	--
KP6	Seabeck Ck.	1 mi. SW of Seabeck (25/1W-29E)	4.76	2/2/61	40-60	43	--	--	2.0	0.4	--
				8/16/61	0.5-1	53	--	--	--	--	--
KP7	Grover's Ck.	3 mi. SW of Kingston (26/2-4M)	6.45	2/27/61	10-15	42	--	--	6.5	3.4	--
				8/15/61	1-2	60	--	--	--	--	--
KP8	Dogfish Ck.	1 mi. N of Poulsbo (26/1-11P)	5.01	2/1/61	30 c/	44	18	0.45b/	9.5	5.2	3.5
				8/15/61	3 c/	60	28	--	12	8.1	5.0
KP9	Clear Ck.	1.2 mi. NE of Silverdale (25/1-16C)	7.46	2/1/61	10-20	44	--	--	5.0	2.5	--
				8/15/61	5-10	58	--	--	--	--	--
KP10	Kitsap Lake	1.1 mi. NW of Bremerton (24/1-8P)	--	2/1/61	--	42	--	--	7.0	2.6	--
				8/16/61	--	72	--	--	--	--	--
KP11	Chico Ck.	1.6 mi. NW of Bremerton (24/1-8E)	12.2	2/1/61	50-75	44	--	--	5.5	1.4	--
				8/16/61	2 c/	58	--	--	--	--	--
KP12	Blackjack Ck.	At Port Orchard (24/1/26J)	12.3	1/31/61	75-150	46	11	0.45b/	5.0	1.4	2.0
				8/15/61	15	58	24	--	8.5	5.3	4.2
KP13	Curley Ck.	0.9 mi. SW of South Colby (23/2-4F)	12.4	1/31/61	50-75	45	--	--	4.5	2.4	--
				8/15/61	5	63	--	--	--	--	--
KP14	Olalla Ck.	1.5 mi. W of Olalla (22/2-5B)	3.88	1/31/61	15-20	46	--	--	5.0	2.5	--
				8/15/61	5-10	57	--	--	--	--	--
KP15	Artondale Ck.	At Artondale (21/1-13P)	2.64	2/2/61	10-15	43	--	--	4.5	2.1	--
				8/15/61	0.5-1	59	--	--	--	--	--
KP16	Burley Ck.	At Burley (22/1-12D)	10.7	1/31/61	79 c/	46	--	--	5.5	2.5	--
				8/15/61	19 c/	55	--	--	--	--	--
KP17	Minter Ck.	3.2 mi. W of Purdy (22/1-20K)	15.0	2/2/61	75-100	43	--	--	3.0	1.0	--
				8/15/61	20	54	--	--	--	--	--
KP18	Coulter Ck.	2.5 mi. SE of Belfair (22/1W-9B)	3.40	2/1/61	75-100	43	--	--	2.5	0.6	--
				8/16/61	10-15	55	--	--	--	--	--
BA1	Unnamed Ck.	0.5 mi. E of Fletcher Bay (25/2-20J)	0.92	2/1/61	15-20	44	--	--	5.5	2.2	--
				8/15/61	0.5-1.5	59	--	--	--	--	--
VA1	Judd Ck.	2.5 mi. S of Vashon (22/3-7L)	4.13	2/2/61	10-15	44	12	0.27b/	5.5	2.6	2.6
				8/16/61	1-3	59	29	--	9.5	6.6	5.1
VA2	Unnamed Ck.	2.5 mi. NW of Vashon (23/3-18N)	2.70	2/2/61	20-30	44	--	--	5.0	2.8	--
				8/16/61	2-4	55	--	--	--	--	--

a/ U.S. Geological Survey drainage area figures. All others determined by Washington State Department of Conservation, Division of Water Resources.

b/ Total iron (concentration not footnoted represents iron in solution at the time of sample collection).

c/ Measured value from records of U. S. Geological Survey.

Parts per million													
								Dissolved Solids					
Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Calculated	Residue on evap. at 180°C	Hardness (as $CaCO_3$)	Specific conductance (Micromhos at 25°)	pH	Color
0.5	27	0	3.2	1.0	0.2	0.4	0.05	39	45	22	52	7.3	5
0.0	36	0	3.6	1.2	--	0.1	0.00	47	--	30	69	7.5	10
--	24	0	--	1.0	--	--	--	--	41	19	47	7.1	25
--	--	--	--	--	--	--	--	--	--	--	83	--	5
--	12	0	--	1.0	--	--	--	--	26	8	23	6.9	15
--	--	--	--	--	--	--	--	--	--	--	61	--	5
0.1	12	0	0.4	1.0	0.2	0.3	0.38	21	30	9	23	6.9	15
0.1	44	0	0.4	1.0	--	0.1	0.05	55	--	33	74	7.4	5
--	15	0	--	0.8	--	--	--	--	27	10	28	6.9	20
--	--	--	--	--	--	--	--	--	--	--	85	--	5
--	9	0	--	0.8	--	--	--	--	25	6	22	6.7	15
--	--	--	--	--	--	--	--	--	--	--	65	--	5
--	25	0	--	3.2	--	--	--	--	86	30	76	6.7	150
--	--	--	--	--	--	--	--	--	--	--	140	--	60
1.6	44	0	8.0	3.0	0.3	4.1	0.18	75	98	45	105	7.1	80
1.3	77	0	4.6	2.8	--	0.6	0.30	101	--	64	140	7.6	35
--	26	0	--	1.8	--	--	--	--	53	22	59	7.1	40
--	--	--	--	--	--	--	--	--	--	--	97	--	20
--	36	0	--	2.0	--	--	--	--	55	28	69	7.1	20
--	--	--	--	--	--	--	--	--	--	--	78	--	10
--	24	0	--	1.2	--	--	--	--	40	20	48	7.3	20
--	--	--	--	--	--	--	--	--	--	--	76	--	5
1.0	18	0	3.6	1.5	0.1	1.8	0.13	36	61	18	48	6.9	60
0.7	54	0	2.8	2.2	--	0.7	0.16	76	--	43	101	7.5	25
--	20	0	--	2.2	--	--	--	--	57	21	58	7.0	60
--	--	--	--	--	--	--	--	--	--	--	81	--	35
--	25	0	--	2.0	--	--	--	--	63	23	59	6.8	80
--	--	--	--	--	--	--	--	--	--	--	83	--	30
--	20	0	--	2.5	--	--	--	--	61	20	51	6.7	120
--	--	--	--	--	--	--	--	--	--	--	118	--	40
--	30	0	--	2.8	--	--	--	--	60	24	65	7.1	70
--	--	--	--	--	--	--	--	--	--	--	94	--	20
--	14	0	--	1.5	--	--	--	--	38	12	35	6.8	35
--	--	--	--	--	--	--	--	--	--	--	81	--	10
--	11	0	--	1.2	--	--	--	--	28	8	26	6.8	30
--	--	--	--	--	--	--	--	--	--	--	77	--	10
--	18	0	--	2.5	--	--	--	--	58	22	66	6.8	45
--	--	--	--	--	--	--	--	--	--	--	124	--	35
1.4	16	0	12	3.2	0.3	3.2	0.08	51	61	24	72	6.8	35
1.1	57	0	8.6	3.2	--	0.6	0.12	92	--	50	118	7.6	50
--	18	0	--	3.0	--	--	--	--	59	24	70	7.1	35
--	--	--	--	--	--	--	--	--	--	--	162	--	10

Table 57. U.S. PUBLIC HEALTH SERVICE DRINKING-WATER STANDARDS. a/

Constituent	Maximum allowable concentration in parts per million	
	Mandatory	Recommended
Alkyl benzene sulfonate (ABS)	--	0.5
Arsenic (As)	0.05	0.01
Barium (Ba)	1.0	--
Cadmium (Cd)	0.01	--
Carbon chloroform extract (CCE)	--	0.2
Chloride (Cl)	--	250
Chromium (Cr^{+6})	0.05	--
Copper (Cu)	--	1.0
Cyanide (CN)	0.2	0.01
Iron (Fe)	--	0.30
Lead (Pb)	0.05	--
Manganese (Mn)	--	0.05
Nitrate (NO_3)	--	45
Phenols	--	0.001
Selenium (Se)	0.01	--
Silver (Ag)	0.05	--
Sulfate (SO_4)	--	250
Total dissolved solids	--	500
Zinc (Zn)	--	5.0

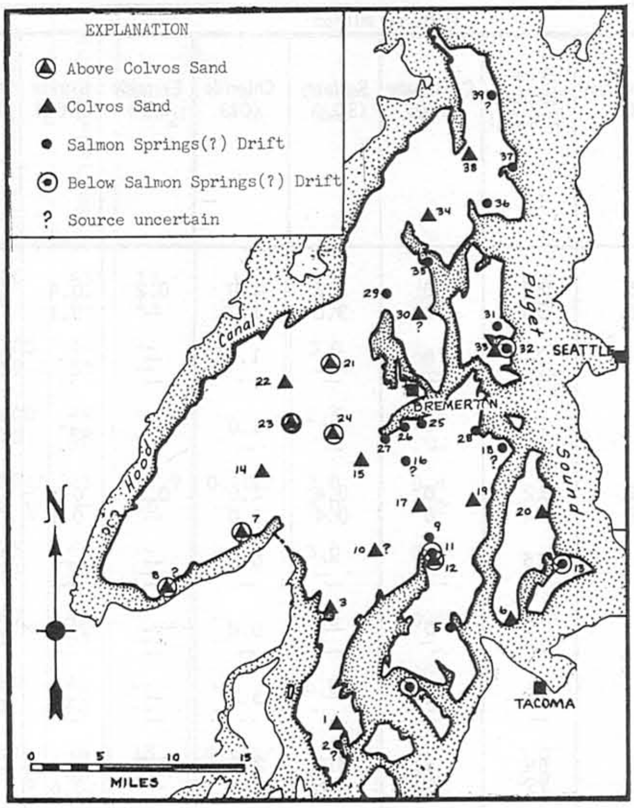

Figure 85. LOCATION OF WELLS AND SPRING SAMPLED FOR CHEMICAL ANALYSIS, AND GEOLOGIC SOURCE OF GROUND-WATER SAMPLES, (Numbers refer to list in table 55).

Table 58. U.S. PUBLIC HEALTH SERVICE RECOMMENDED UPPER CONCENTRATION LIMITS FOR FLUORIDE IN DRINKING WATER a/

Annual Average of Maximum Daily Air Temperature (°F)	Parts per million Fluoride (F)
50.0 - 53.7	1.7
53.8 - 58.3	1.5
58.4 - 63.8	1.3
63.9 - 70.6	1.2
70.7 - 79.2	1.0
79.3 - 90.5	0.8

GROUND-WATER QUALITY

Thirty-nine ground-water sources (38 wells and one spring) on the Kitsap Peninsula and certain adjacent islands were sampled for chemical analysis (table 55). Many of the same sources were resampled 6 months later to check for variation in concentrations of chemical constituents. The sampling points are well distributed throughout the area (fig. 85). As a result, the characteristic chemical quality of ground water from the principal water-producing zones in use at the time of this study has been reasonably well defined. Furthermore, these data suggest the chemical characteristics and the problems that will be found in future search for more water.

GENERAL CHEMICAL CHARACTERISTICS

The chemical quality of ground-water samples collected as part of this study in general can be classified as good. In most samples the dissolved-solids content is less than 150 ppm, and the principal constituents are calcium (Ca^{+2}), magnesium (Mg^{+2}), bicarbonate (HCO_3^{-1}), and silica (SiO_2) (see tables 55 and 60).

The suitability of water for industrial and domestic uses depends largely on the concentration of constituents dissolved in the water and on various properties of the water. Water quality tolerances for several industrial applications are given in Table 59. A brief discussion of several of the important constituents and properties of Kitsap Peninsula ground water follows.

CHARACTER OF SPECIFIC CONSTITUENTS

SILICA

Although silica is neither physiologically significant

a/ Data after U.S. Public Health Service, 1962.

Table 59. WATER QUALITY TOLERANCES FOR INDUSTRIAL APPLICATION. Allowable limits in parts per million, except pH, color, and turbidity. a/

Industrial Application	Silica (SiO_2)	Iron, manganese, or iron + manganese	Calcium (Ca)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Fluoride	Total solids	Hardness (as $CaCO_3$)	Alkalinity (as $CaCO_3$)	pH	Color	Turbidity
AIR CONDITIONING	--	0.5	--	--	--	--	--	--	--	--	--	--
BAKING b/	--	0.2	--	--	--	--	--	4	--	--	10	10
BOILER FEED: 0-150 psi	40	--	--	50	200	--	--	75	--	8.0+	80	20
150-250 psi	20	--	--	30	100	--	--	40	--	8.5+	40	10
250 psi & up	5	--	--	5	40	--	--	8	--	9.0+	5	5
BREWING b/: Light beer	--	0.1	100-200	--	--	1.0	500	--	75	6.5-7.0	--	10
CANNING b/: Legumes	--	0.2	--	--	--	--	--	25-75	--	--	--	10
General	--	0.2	--	--	--	--	--	--	--	--	--	10
CARBONATED BEVERAGES b/	--	0.2	--	--	--	0.2	850	250	50	--	10	2
COOLING	--	0.5	--	--	--	--	--	50	--	--	--	50
ICE (RAW WATER) b/	10	0.2	--	--	--	--	300	--	30-50	--	5	1-5
LAUNDERING	--	0.2	--	--	--	--	--	50	--	--	--	--
PLASTICS: Clear, undercolored	--	0.02	--	--	--	--	200	--	--	--	2	2
PAPER PULP: Groundwood	--	0.5	--	--	--	--	--	180	--	--	20	50
Kraft pulp	--	0.1	--	--	--	--	300	100	--	--	15	25
Soda & sulfite	--	0.05	--	--	--	--	200	100	--	--	10	15
HL-Grade Light	--	0.05	--	--	--	--	200	50	--	--	5	5
RAYON (VISCOSE) PULP:												
Production	25	0.3	--	--	--	--	100	8	50	--	5	5
Manufacture	--	0.0	--	--	--	--	--	55	--	7.8-8.3	--	.3
TANNING	--	0.2	--	--	--	--	--	50-135	135	8.0	10-100	20
TEXTILES: General	--	0.25	--	--	--	--	--	20	--	--	20	5
Dyeing	--	0.25	--	--	--	--	--	20	--	--	5-20	5
Wool scouring	--	1.0	--	--	--	--	--	20	--	--	70	--
Cotton bandage	--	0.2	--	--	--	--	--	20	--	--	5	5

a/ American Water Works Association, 1950, Water quality and treatment: Am. Water Works Assoc. Manual, 2d ed., tables 3-4, p. 66-67.

b/ Must conform with U. S. Public Health Service standards for drinking water (tables 57 and 58).

to human beings nor of importance in irrigation water, it can be a problem in industrial water supplies. For example, silica deposits can cause hot spots and rupture in boiler tubes. Also, silica deposits on blades of steam turbines affect the efficiency of the turbine. Many of the ground-water samples from the Kitsap Peninsula and certain adjacent islands contain as much as 35 to 40 ppm of silica. The higher silica concentrations of ground water in the Kitsap Peninsula correlate approximately with deeper and geologically older water-bearing zones (table 60 and fig. 86). This characteristic precludes the use of some untreated deep well water for certain industrial applications, such as boiler feed and ice production.

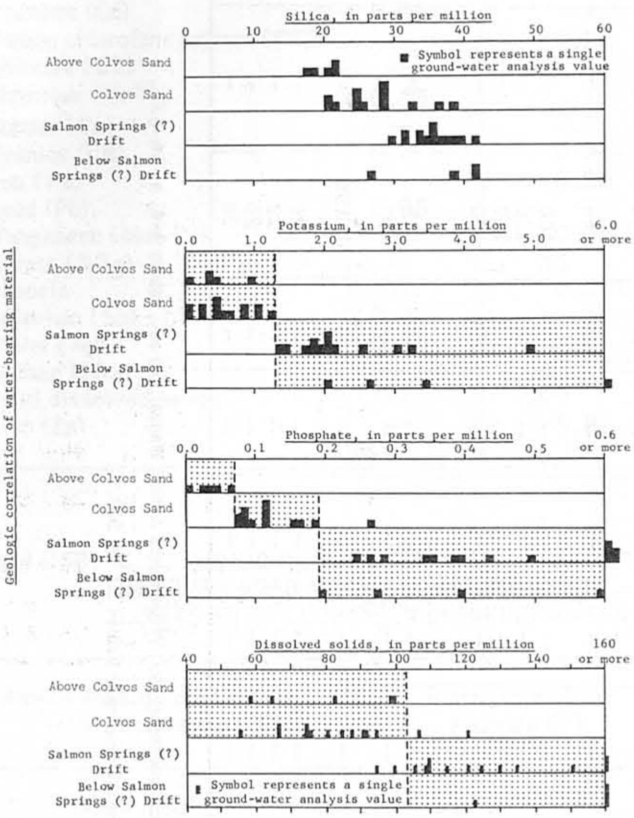

Figure 86. DISTRIBUTION OF SILICA, POTASSIUM, PHOSPHATE, AND DISSOLVED-SOLIDS CONCENTRATIONS RELATIVE TO GEOLOGIC SOURCE OF GROUND WATER OF THE KITSAP PENINSULA AND CERTAIN ADJACENT ISLANDS. Dashed vertical lines and stippled areas emphasize concentration variation between formations or groups of formations. Analyses of samples from location numbers 8 and 16 (table 55) are not included because geologic correlation of the water-bearing zones is extremely uncertain.

IRON

Studies have shown that an appreciable quantity of ferrous iron can remain in solution when water is in an oxygen-poor environment (for example, see Hem and Cropper, 1959). The water-producing zones of many wells represent such environments. However, when the water is brought from oxygen-poor to oxygen-rich surroundings such as the atmosphere, ferrous iron is oxidized to the ferric state, which precipitates from solution as the reddish-brown precipitate ferric hydroxide, $Fe(OH)_3$ (or more correctly, $Fe_2O_3 \cdot 3H_2O$).

Three criteria determine the reliability of iron-concentration data for ground water. First, the sample must be collected directly from the well, before the iron has a chance to precipitate from solution during storage. Second, the well must be thoroughly pumped before the sample is taken, to insure that all loose rust from the tubing and well casing have been removed and that the sample represents water taken directly from the water-producing zone, not from the tubing, tank, or well casing after storage. Finally, the sample must be clear and free from sediment at the time it is obtained from the well. During the collection of several ground-water samples whose analyses appear in table 55, either one or more of the above prerequisites could not be met, and the analyses may, as a result, indicate only the general magnitude of iron concentration but not the exact value. In spite of this lack of strict control, the analyses show that several samples contain appreciable concentrations of iron and that in a few samples these concentrations not only exceed those allowable for various industrial applications, but they exceed the U.S. Public Health Service (1962) suggested upper limit of 0.30 ppm for public supply as well.

Analyses of samples from 20 of the 39 ground-water sources show iron concentrations greater than 0.10 ppm. Little consistent correlation exists between geologic formation and iron concentration, although the greatest percentage of higher iron concentrations (more than 0.10 ppm) are found in water from formations below the Colvos Sand. Only a rough correlation exists between geographic location and higher iron content. In two broad areas, however, concentrations consistently exceed 0.10 ppm (see fig. 87). The somewhat meager data suggest that within these two areas most wells, both present and future, would have similar iron concentrations.

Among the iron concentrations of more than 0.10 ppm, 10 exceed 0.30 ppm, and of these, 6 are termed "total iron" and include all forms of soluble iron plus iron extracted from material suspended in the sample. Iron concentrations for the remaining 4 ground-water samples represent iron in solution at the time of sampling and range from 0.45 to 0.62 ppm. The source wells are scattered throughout the areas of consistently high iron concentration.

FLUORIDE

Ground water of the Kitsap Peninsula is low in fluoride content. The U.S. Public Health Service (1962), as well as many state and local health agencies, recommends about 1.0 ppm of fluoride in drinking water for children during the tooth-calcification period. Assuming an average maximum daily air temperature in the 55 to 60°F range for the Kitsap Peninsula and certain adjacent islands, the upper fluoride concentration limit for drinking water, as recommended by the U.S. Public Health Service (1962), is between 1.3 and 1.5 ppm (table 58). However, all ground-water analyses for the area of study show less than 0.4 ppm of fluoride and only three show more than 0.1 ppm.

NITRATE

The highest nitrate concentrations are found, almost without exception, in water from shallow wells. Shallow ground water in some places is subjected to the influence of nitrate derived from organic decay or chemical fertilizer of surface or near-surface origin. The maximum nitrate concentration of the samples analyzed is 10 ppm, which is well

Table 60. CONCENTRATION AVERAGES AND RANGES FOR CONSTITUENTS AND PROPERTIES OF GROUND WATER FROM THE PRINCIPAL FORMATIONAL UNITS IN THE KITSAP PENINSULA AND ADJACENT ISLANDS, WASHINGTON. Analyses of water from sampling site numbers 8 and 16 (table 55) are not included because geologic correlation of water-bearing zones is uncertain.

Constituent (or property)	Water-bearing formational unit							
	Above Colvos Sand		Colvos Sand		Salmon Springs(?) Drift		Below Salmon Springs(?) Drift	
Number of samples	5		14		14		4	
	Average	Range	Average	Range	Average	Range	Average	Range
Well depth (in feet)	60	18 - 88	135	0 - 224	297 a/	62 - 832a/	515	353 - 813
Parts per million								
Silica (SiO_2)	19	17 - 21	26	20 - 38	35	29 - 41	36	26 - 41
Calcium (Ca)	13	7.0 - 22	8.4	5.5 - 11	17	9.0 - 30	24	12 - 45
Magnesium (Mg)	2.6	1.5 - 3.6	5.9	2.9 - 12	6.1	2.2 - 11	12	1.5 - 19
Sodium (Na)	6.4	2.8 - 11	4.6	3.1 - 7.5	8.9	4.6 - 20	22	10 - 43
Potassium (K)	.4	.0 - .9	.5	.0 - 1.2	2.3	1.3 - 4.9	3.8	2.0 - 7.4
Bicarbonate (HCO_3) b/	53	34 - 90	55	35 - 89	96	70 - 156	190	94 - 346
Sulfate (SO_4)	5.4	.2 - 15	3.8	.0 - 20	3.2	.0 - 15	2.0	.3 - 6.6
Chloride (Cl)	4.0	1.2 - 9.0	3.1	1.2 - 6.2	4.5	1.2 - 22	5.0	1.5 - 8.8
Nitrate (NO_3)	2.6	.1 - 4.9	2.8	.1 - 10	.5	.0 - 3.4	.2	.1 - .5
Phosphate (PO_4)	.03	.00 - .06	.12	.07 - .26	.63	.24 - 2.0	.36	.19 - .59
Dissolved Solids (calculated)	80	58 - 99	83	55 - 120	125	94 - 180	201	122 - 338
Hardness (as $CaCO_3$)	43	29 - 61	45	27 - 77	67	46 - 106	110	36 - 190
pH (logarithmic averages)	6.5	6.1 - 7.9	7.3	6.8 - 8.0	7.8	7.3 - 8.5	7.9	7.6 - 8.3

a/ Sampling site number 18 (table 55) not included because well depth is unknown.
b/ Includes carbonate (CO_3) calculated as HCO_3.

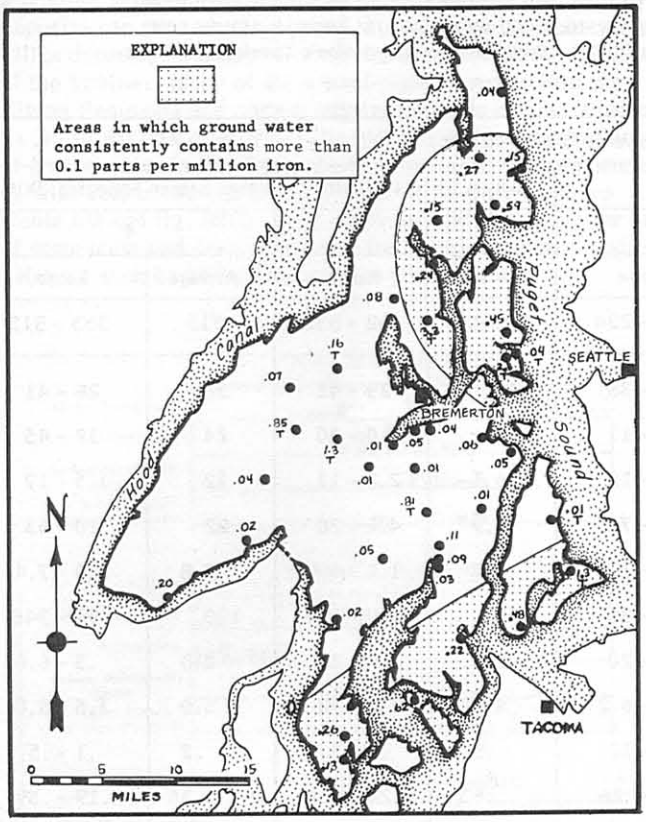

Figure 87. MAP SHOWING IRON CONCENTRATION (IN PARTS PER MILLION) OF GROUND-WATER SAMPLES FROM THE KITSAP PENINSULA AND CERTAIN ADJACENT ISLANDS. "T" below iron value indicates total iron concentration. Data from table 55.

below the recommended 45 ppm upper limit for drinking water (see U.S. Public Health Standards, table 57).

DISSOLVED SOLIDS

Ground water of the Washington coastal region, including Kitsap County and certain adjacent areas, is characterized by a low dissolved-solids content. Only one sample (site 13), from a deep well on Maury Island, has a dissolved-solids content greater than 200 ppm, and only 19 of the 39 ground-water samples analyzed contain more than 100 ppm of dissolved solids. A definite, though by no means universal, relationship exists between depth, geologic age, and dissolved-solids content (see table 60 and fig. 86). Because several industrial water applications have a low dissolved-solids tolerance (see table 59), the depth-dissolved solids relation may become important in the future, if greater demand for water requires the utilization of deeper water-bearing zones.

HARDNESS

On the basis of the arbitrary hardness classification discussed in the section on water quality standards (p. 149), most of the analyzed ground water samples of the Kitsap Peninsula can be considered soft (less than 60 ppm) or only moderately hard (61-120 ppm). Hardness of the water from only one well (number 13) is greater than 120 ppm.

As with dissolved solids and silica, a general relation exists between hardness of water and depth--that is, the deeper and geologically older formations often yield harder water. In the future, this relation may present problems similar to those suggested for dissolved solids.

CHEMICAL QUALITY VARIATION WITH TIME

Table 55 shows that one-third of the initially-sampled wells were resampled for partial analyses after about 6 months. This was done to check for seasonal change in chemical and physical qualities of the ground water. A comparison of the two groups of analyses shows appreciable change in chemical quality of water from only one source during the 6-month interval. The single exception was the water from a 55-foot well (see table 55, well 8) adjacent to the Hood Canal, 20 miles southwest of Bremerton. The well was sampled first in March 1961, during a period of abundant precipitation and moderate water use, and the water was found to have dissolved-solids content of 118 ppm. The same well was sampled again in August 1961, during a dry period of intensive water use. The water then had a dissolved-solids content of 312 ppm and sodium and chloride were the principal constituents. This is clearly an example of contamination by salt water from the Hood Canal. Contamination of this type can occur where wells are adjacent to, and hydraulically connected with, the ocean or other salt water body.

Although only one occurrence of salt-water contamination is shown by the analyses in this report, data of Sceva (1957, tables 5 and 7) indicate that wells in other near-shore areas in Kitsap County are subject also to the same type of contamination. Several partial analyses taken from Sceva's report are shown in the table that follows. With one exception the wells are located near Hansville, on the northern tip of the Kitsap Peninsula. In addition, Sceva (p. 56) cites several extreme examples of contamination that involved wells in and near Winslow on Bainbridge Island.

The foregoing data suggest that almost any near-shore area on the Kitsap Peninsula and certain adjacent islands is subject to salt-water contamination. With these exceptions, however, the chemical quality of ground water can be expected to show little change, even over long periods of time.

Table 61. PARTIAL ANALYSES OF SAMPLES OF GROUND WATER PROBABLY INFLUENCED BY SALT-WATER CONTAMINATION. a/

Well location code a/	Depth of well, (feet below mean sea level)	Parts per million		
		Chloride (Cl)	Hardness (as $CaCO_3$)	Dissolved solids
24/2-9L1	149	897	226	--
28/1-12R1	24	250	318	--
28/1-13A1	47	690	522	--
28/2-7M2	154	98	224	--
28/2-16K2	110	212	204	--
28/2-22B1	29	489	335	1,230

a/ Data and well numbers after Sceva, 1957, tables 5 and 7, p. 95-176.

THE RELATIONSHIP BETWEEN GEOLOGY AND CHEMICAL QUALITY

Well-drillers' records and surface geology indicate that the producing intervals of most of the sampled wells can be assigned to specific geologic formations or to a particular sequence of formations. This information and the chemical analyses can be used to determine the chemical characteristics of water from each geologic formation or group of formations. Finally, when chemical characteristics have been determined, they in turn can be used to correlate the water-bearing zones of wells for which little or no geologic information is available.

Results of the combined geologic and chemical correlations of water-bearing zones appear in table 60 and figure 86. Table 60 shows that, on the basis of average values, the concentrations of most constituents exhibit appreciable change from formation to formation. Three chemical characteristics--the concentrations of potassium and phosphate and dissolved-solids content--can be used in a general way to distinguish between groups of formations. Variations in these three items (fig 86) provide reasonable to good criteria for the separation of the Colvos Sand and younger formations from the Salmon Springs(?) Drift and older, deeper formations. In addition, a difference exists between phosphate concentrations in ground water above the Colvos Sand and in that of the Colvos Sand itself. Unfortunately, the remaining constituents have wide and overlapping spreads of values (table 60), as shown, for example, by the distribution of silica concentrations in figure 86.

A qualitative means of distinguishing ground water from the different formations is through use of a graph on which the potassium concentration of a well water is plotted against its phosphate concentration (see fig. 88). Ground water from the same formation or formations is segregated into fairly distinct groups. The graph and data similar to that of table 60, proved useful in the correlation of water-bearing zones for which no reliable geologic information was available. The resulting correlations helped to define the regional geology in some areas where well-drillers' records and surface geology were uncertain.

Reasons for the chemical variations observed in table 60 are undoubtedly many in number and complex in nature. Several generalizations can be made, however. The parallel between increased dissolved-solids concentration and increased geologic age is a common but not universal characteristic not only in the Kitsap area but in other regions as well. In general, water of the older, deeper formations has been con-

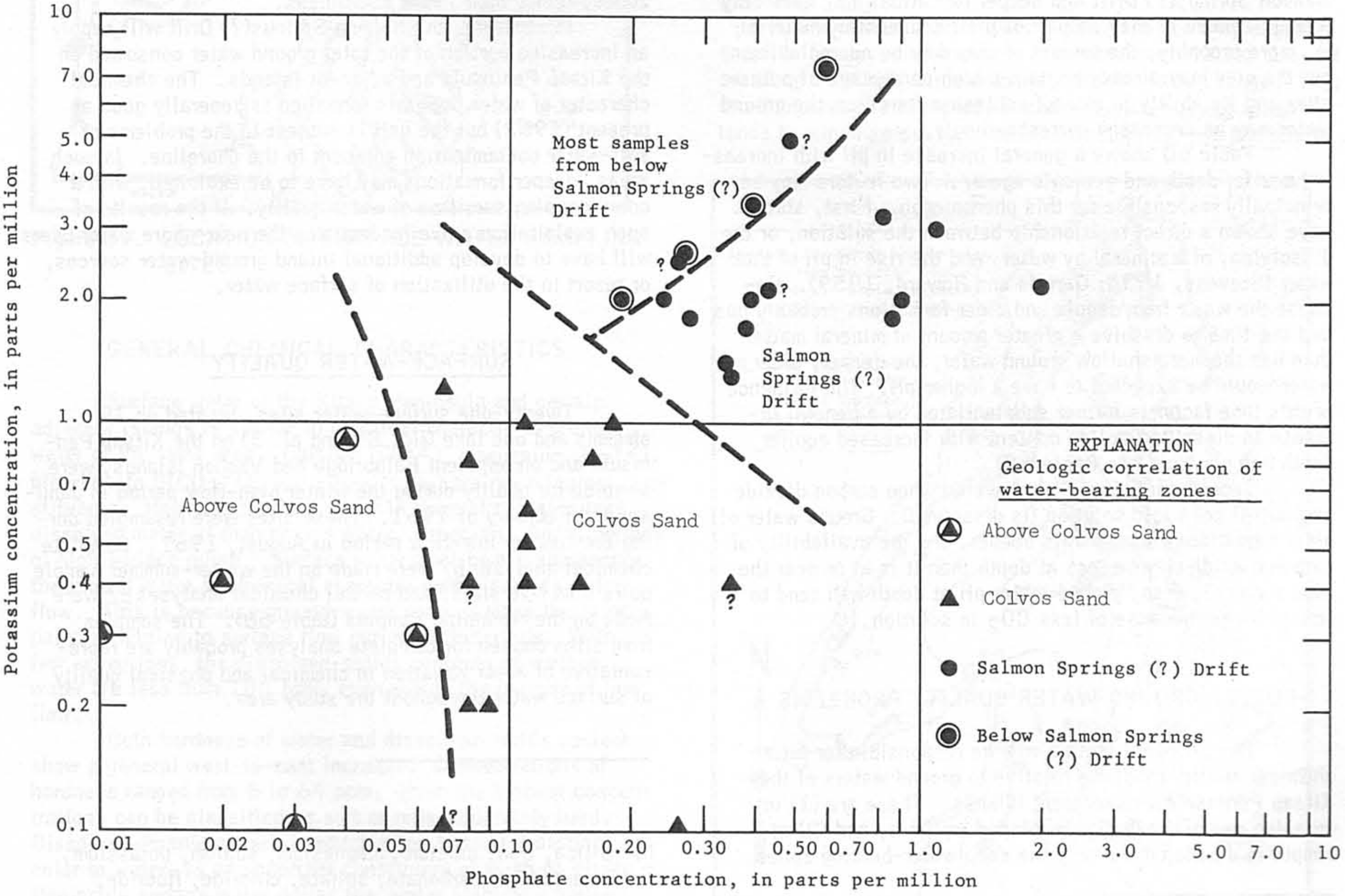

Figure 88. RELATION BETWEEN POTASSIUM CONCENTRATION, PHOSPHATE CONCENTRATION, AND WATER-BEARING FORMATION FOR GROUND WATER OF THE KITSAP PENINSULA AND CERTAIN ADJACENT ISLANDS. Query denotes doubtful formation correlation, based on insufficient geologic or chemical evidence. Data are from table 55.

fined a longer period of time within the water-bearing zones. Thus it has had a greater opportunity to dissolve the slightly soluble mineral constituents of the rock materials. Conversely, water in the shallower, generally younger formations not only has had less "residence" or contact time but also has been subjected much more to the diluting effects of water percolating downward from the surface than has the deeper water.

The marked increase in phosphate concentration with increasing depth is puzzling. The only probable mineral source of phosphate in the aquifer materials is apatite, a common but minor constituent of many igneous and metamorphic rocks. Apatite is relatively insoluble and as a result, it tends to accumulate in sedimentary materials derived from the weathering of igneous and metamorphic rocks. The sediments of the Salmon Springs(?) Drift possibly have a high accessory apatite content, thus providing a more abundant source of phosphate than the other formations.

Potassium concentrations, just as those of phosphate, are distinctly greater in water-bearing zones below the Colvos Sand and the reasons for this phenomenon are uncertain. Even though potassium is an abundant constituent of many rocks, its concentration in water generally is low because some clay minerals remove it selectively for use within their mineral structure. The greater concentrations at depth therefore suggest at least two possibilities: water-bearing zones in the Salmon Springs(?) Drift and deeper formations may have only a small amount of clay as part of their sedimentary material; or, more probably, the amount of clay may be appreciable, but the clay may already contain a high percentage of potassium and its ability to extract potassium ions from the ground water may be decreased correspondingly.

Table 60 shows a general increase in pH with increasing aquifer depth and geologic age a/. Two factors may be principally responsible for this phenomenon. First, studies have shown a direct relationship between the solution, or the dissolving, of a mineral by water, and the rise in pH of that water (Stevens, 1934; Garrels and Howard, 1959). Because the water from deeper and older formations probably has had the time to dissolve a greater amount of mineral matter than has the more shallow ground water, the deeper, older water would be expected to have a higher pH. The influence of this time factor is further substantiated by a general increase in dissolved-solids content with increased aquifer depth and geologic age (table 60).

Second, solution pH is lowered when carbon dioxide gas (CO_2) goes into solution (is dissolved). Ground water of older formations in general is deeper, and the availability of carbon dioxide may be less at depth than it is at or near the land surface. If so, ground-water pH at depth will tend to remain higher because of less CO_2 in solution.

FUTURE GROUND-WATER QUALITY PROBLEMS

Two principal factors will be responsible for future chemical quality problems relative to ground waters of the Kitsap Peninsula and adjacent islands. These are (1) increasing use of presently-developed aquifers, and (2) attempts to develop more fully the deep water-bearing zones.

As demand for water increases, more water will be withdrawn from the aquifers. Not only will intensive utilization probably deplete the water-bearing zones in some areas, but also it will lead to contamination by salt water in other areas. Contamination is already a problem in some parts of the peninsula and nearby islands immediately adjacent to waters of the Puget Sound. The wells most readily affected are those that derive their water from depths in the range from sea level to roughly 200 feet below sea level. In the future, as the need for dependable water supplies increases, the areas susceptible to seawater intrusion will have to be carefully exploited. Safe pumping yields for the zones in question should be determined by hydrologic investigation, and the resulting data should be used to govern water utilization.

Deeper zones undoubtedly will be explored in an attempt to provide a sufficient quantity of water for the growing population of the Kitsap area. As shallow-producing zones such as those of the Colvos Sand and younger formations are used to their capacity, the Salmon Springs(?) Drift, and in some places even older units, may become the principal producers. Although water of the Salmon Springs(?) Drift in general is of good chemical quality, water of the older, deeper formations is, in some places, poor in quality and unsuitable for many industrial applications, without treatment. This fact, coupled with the sporadic production of these deeper zones, limits their future usefulness.

In summary, the Salmon Springs(?) Drift will supply an increasing portion of the total ground water consumed on the Kitsap Peninsula and adjacent islands. The chemical character of water from this formation is generally good at present (1962) but the unit is subject to the problems of salt-water contamination adjacent to the shoreline. In such areas, deeper formations may have to be exploited, with a corresponding sacrifice of water quality. If the results of such exploitation prove inadequate, the near-shore water users will have to develop additional inland ground-water sources, or resort to the utilization of surface water.

SURFACE-WATER QUALITY

Twenty-one surface-water sites, located on 19 streams and one lake (fig. 89 and pl. 3) on the Kitsap Peninsula and on adjacent Bainbridge and Vashon Islands, were sampled for quality during the winter high-flow period in January and February of 1961. These sites were resampled during the summer low-flow period in August, 1961. Complete chemical analyses b/ were made on the winter-summer sample pairs from five sites, and partial chemical analyses c/ were made on the remaining samples (table 56). The samples from sites chosen for complete analyses probably are representative of areal variation in chemical and physical quality of surface water throughout the study area.

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a/ The pH of a solution is a measure of its hydrogen-ion concentration, or its acidity; a low pH value indicates higher hydrogen-ion concentration and greater acidity. A pH of 7 is considered neutral, whereas a value less than 7 is termed acid, and a value greater than 7 is termed alkaline.

b/ Silica, iron, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, phosphate, dissolved solids, hardness, specific conductance, pH, and color were determined.

c/ Calcium, magnesium, bicarbonate, carbonate, chloride, dissolved solids, hardness, specific conductance, pH, and color were determined.

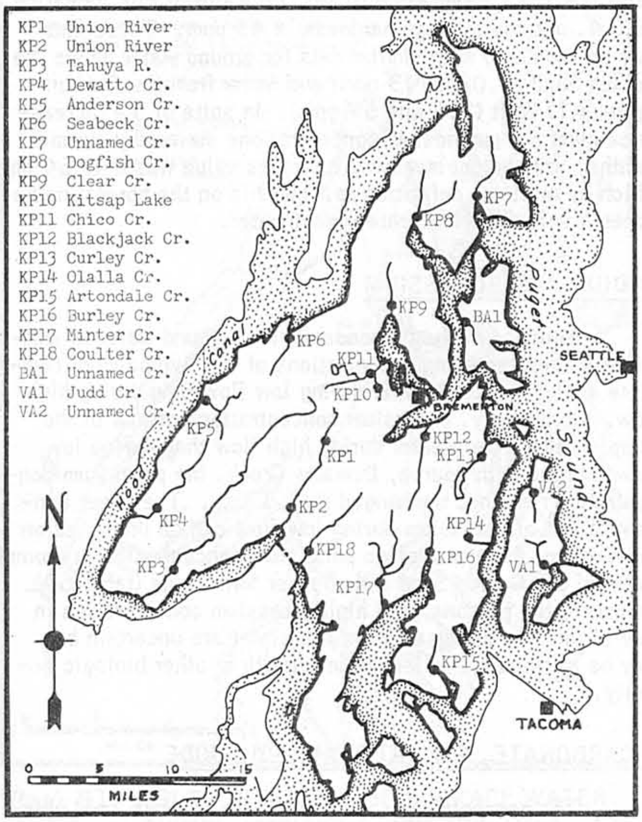

Figure 89. LOCATION OF SURFACE-WATER SAMPLING SITES.

GENERAL CHEMICAL CHARACTERISTICS

Surface water of the Kitsap Peninsula and certain adjacent islands is similar in chemical character to ground water of the same area. Calcium (Ca^{+2}), magnesium (Mg^{+2}), bicarbonate (HCO_3^{-1}), and silica (SiO_2) are the principal constituents. However, surface water in general contains less dissolved material than ground water, especially during periods of high surface runoff. Surface water most nearly approaches the ground water in chemical character during periods of low flow. This is because ground-water sources make the principal contribution to surface flow during such periods. With few exceptions, the dissolved-solids contents of surface water are less than 100 ppm, even during the periods of low flow.

Both hardness of water and dissolved-solids content show a general west-to-east increase. Concentrations of hardness ranged from 6 to 64 ppm. Even the highest concentrations can be classified as soft or only moderately hard. Dissolved organic material, which often imparts a distinct color to water, is an important constituent of much of Kitsap Peninsula surface water during the winter high-flow period. Highest color values occur in water of the eastern part of the study area. Meager data indicate that in at least one place the concentration of iron in solution is sufficient to be bothersome. Except for organic-color and iron problems, surface water of the Kitsap Peninsula is of favorable chemical quality.

SPECIFIC CONSTITUENTS AND PROPERTIES: THEIR SIGNIFICANCE AND SEASONAL VARIATION

SPECIFIC CONDUCTANCE

The specific conductance of a water sample can be used as a rough measure of the dissolved-solids content of the sample--specific conductance is usually about 1-1/2 times the inorganic dissolved-solids content. Thus, specific conductance is a useful tool in the evaluation of general areal and seasonal changes in surface-water quality. For example, the specific conductances of winter (January and February) samples at the 21 surface-water sampling locations (fig.90) show a distinct increase from west to east. This increase probably is the result of dilution by greater precipitation on the generally higher, western part of the peninsula. The parallel between higher stream discharge rates and low specific conductances supports such a theory.

A comparison of winter and summer specific conductances for any particular stream shows a distinct increase in summer--in several streams 300 percent or more--and indicates the influence of more concentrated ground water during periods of little precipitation and low flow. The winter-to-summer change is more extreme in the western part of the area, where dilute precipitation runoff is an important factor during the winter.

Six winter-summer sample pairs showed only a small specific-conductance increase in the summer. Kitsap Lake at sampling site KP10 for example, showed little change. This small increase is expected, because such a body of water tends to minimize seasonal change through storage and mixing.

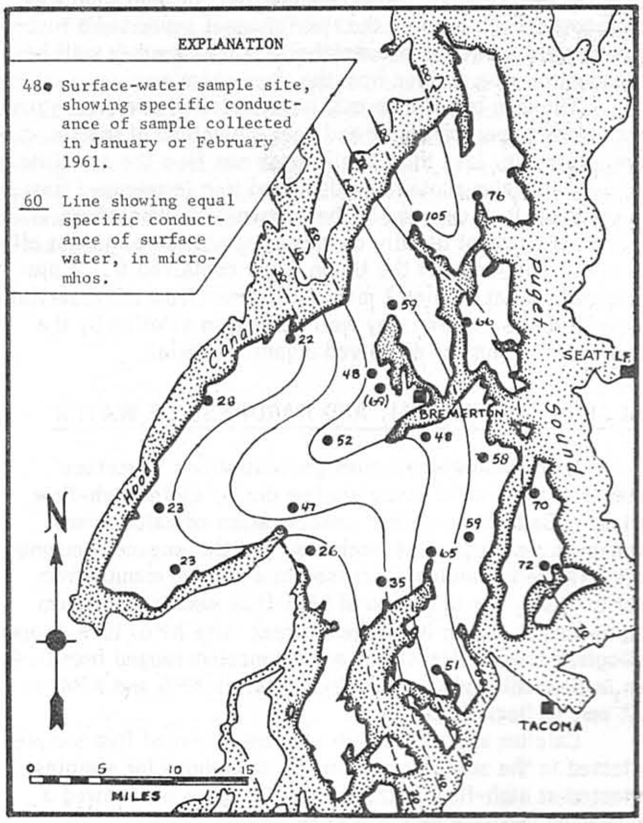

Figure 90. SPECIFIC CONDUCTANCE OF SURFACE WATER DURING JANUARY-FEBRUARY 1961. Contours apply only to land area. Data are from table 56.

The Union River at McKenna Falls (site KP1) shows a similar slight change for a similar reason. Here, the streamflow is almost entirely from a municipally-owned catchment and storage reservoir less than 1 mile upstream. Burley (site KP16), Olalla (site KP14), Curley (site KP13), and Dogfish (site KP8) Creeks all show only a moderate specific-conductance increase in the summer. Three of these sites have only a small winter-to-summer flow-rate change. These facts indicate that precipitation contributed little direct runoff to the winter streamflow at the time of sample collection, and consequently, neither quantity nor quality of flow changed much between the different times of sample collection.

SILICA

Silica was determined on five sample pairs. One of the pairs, Union River at McKenna Falls (site KP1), shows no winter-to-summer change in silica concentration for reasons discussed in the paragraph above. The other four pairs (VA1, KP4, KP12 and KP8) show great increases in concentration. This increase can be attributed to the influence of higher-silica ground water during summer periods of little runoff.

IRON

Iron was determined on five samples collected in the winter. The high concentrations of iron (as much as 0.45 ppm) reflect the appreciable amount of organic and inorganic sediment in the samples at the time of collection. Only the Union River at McKenna Falls (site KP1) was analyzed for iron content during low flow in August 1961. At that time the water was virtually clear, yet the iron concentration was 0.22 ppm. Furthermore, the river channel supported a rust-colored algal growth whose metabolic processes may well be dependent on iron derived from the river water.

The iron in solution may have as its source an oxygen-poor reducing enviroment on and near the bottom of the Union River reservoir, less than 1 mile upstream from the sampling site. When water containing dissolved iron is released from the reservoir it is exposed to the oxygen-rich atmosphere. Such an enviroment usually causes precipitation of almost all the iron. The fact that the Union River contained 0.22 ppm dissolved iron at a point 1 mile downstream from the reservoir suggests that some iron may well be held in solution by the complexing actions of dissolved organic material.

CALCIUM, MAGNESIUM, AND HARDNESS OF WATER

Calcium and magnesium concentrations in surface water from the area of study are low during winter high-flow periods. Both the combined concentration of calcium and magnesium, expressed as hardness, and the amount of magnesium relative to calcium increased in a general manner from west to east. For the group of high-flow samples, calcium ranged from 2.0 ppm in Seabeck Creek (site KP6) to 9.5 ppm in Dogfish Creek (site KP8), and magnesium ranged from 0.4 ppm in Seabeck and Dewatto Creeks (sites KP6 and KP4) to 5.2 ppm in Dogfish Creek.

Calcium and magnesium concentrations of five samples collected in the summer were greater than those for samples collected at high-flow in the winter. Magnesium showed a pronounced increase from winter to summer samples. The ratio "average ppm Ca:average ppm Mg" for Dewatto, Judd, Blackjack, and Dogfish Creeks decreased from 2.4 for the winter group to 1.7 for the summer group, and the average concentration of hardness increased from 24 ppm to 48 ppm. The decrease in the ratio probably indicates the influence of ground water derived primarily from Colvos Sand. The ratio "average ppm Ca:average ppm Mg" for water of this formation is 1.4, and the average hardness is 45 ppm. These data may be compared with similar data for ground water above the Colvos Sand (5.0 and 43 ppm) and water from the Salmon Springs(?) Drift (2.8 and 67 ppm). In spite of the increase in calcium and magnesium concentrations during dry summer months, the highest measured hardness value was only 64 ppm, which by arbitrary definition (p. 149) is on the borderline between a soft and a moderately hard water.

SODIUM AND POTASSIUM

Because of the preponderance of ground water in summer low flow, sodium concentrations of the five pairs of complete analyses were greater during low flow than during high flow. Conversely, potassium concentrations of four of the sample pairs were greater during high flow than during low flow. In the fifth source, Dewatto Creek, the potassium concentration remained unchanged at 0.1 ppm. The lower concentrations of potassium during low flow can be predicted on the basis of the low average potassium concentration in ground water of the Colvos Sand and younger formations (table 60). However, the reasons for a high potassium concentration in four of the five streams during the winter are uncertain but may be attributable to less plant growth or other biologic activity.

BICARBONATE, SULFATE, AND CHLORIDE

The concentrations of bicarbonate, sulfate, and chloride in surface-water samples showed no unexpected variations. Concentrations of the three constituents in winter samples were lower than in summer samples, but only bicarbonate showed an appreciable increase in the summer when surface water is derived largely from spring and seep discharge, and approaches ground water in chemical character.

NITRATE

The concentration of nitrate shows a universal winter-to-summer decrease. Greater pickup of organic decay material by winter rain runoff and the summer increase in biologic activity are probably the principal reasons for such a decrease.

DISSOLVED SOLIDS AND WATER COLOR

Dissolved-solids content was determined by the residue-on-evaporation method on all 21 winter-collected surface-water samples. Most of these data were almost numerically equal to or greater than specific conductance data, whereas a dissolved-solids content for water normally is two-thirds to three-fourths the specific conductance. Furthermore, the calculated dissolved-solids contents for the five complete analyses were substantially less than those determined by the residue method. These data and the color data indicate that the water contains an appreciable amount of dissolved organic material. Such material generally is highly colored, whereas dissolved inorganic constituents usually impart no color to water. During the winter, the more highly colored water samples were collected from a group of streams in the eastern part of the area, where the organic material

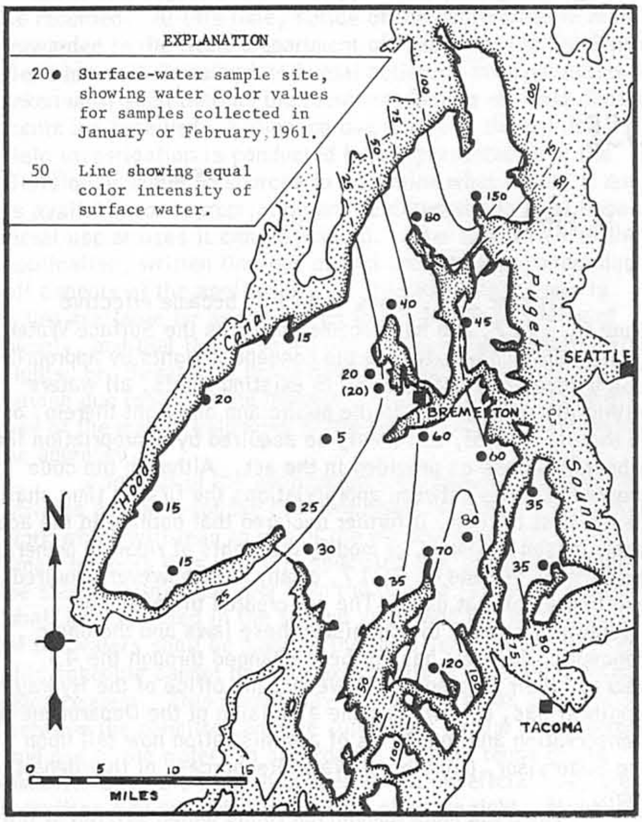

Figure 91. COLOR INTENSITY OF SURFACE WATER DURING JANUARY-FEBRUARY 1961. Contours apply only to land areas. Data are from table 56.

seems to be derived primarily from flat, and in some places marshy, pasture areas (see fig. 91). In most streams the color intensity, and presumably the organic content as well, decrease during the summer months when ground water is the principal source of stream flow.

pH

The pH of samples collected in the winter was remarkably uniform throughout the area and ranged from 6.7 to 7.3. Of the five complete analysis pairs of winter and summer samples, the pH ranged from 6.8 to 7.3 (high flow) and 7.4 to 7.6 (low flow). The difference between the two ranges probably is the result of several factors, the principal ones being differences in biologic activity rates, higher summer water temperatures, and the greater influence of higher-pH ground water.

FUTURE SURFACE-WATER QUALITY PROBLEMS

Beside municipal utilization of Union River water, surface streams and springs on the Kitsap Peninsula and certain adjacent islands are utilized for domestic and irrigation purposes. However, the chemical quality problems are now few in number. Concentration of iron and a stagnant odor present problems in the utilization of Union River water as a public supply. These two characteristics become objectionable only at maximum concentration and intensity in the late summer and fall. Problems similar to those of the Union River undoubtedly will be experienced if an additional public supply reservoir is constructed on Gold Creek, roughly 2 miles northwest of the present reservoir on Union River. In other areas, high color and organic content of the water are objectionable, but these properties do not require treatment at this time.

In the future, a growth of both population and industry may produce more problems, not only in the form of water quality requirements but through pollution as well. To guard against undesirable long term chemical and biological change, several of the more important streams should be monitored on at least a quarter-year basis.